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AN ELEMENTARY TEXT-BOOK
OF
BOTANY.

TRANSLATED FROM THE GERMAN OF

Dr. K. PRANTL,
PROFESSOR OF BOTANY IN THE ROYAL ACADEMY OF FORESTRY,
ASCHAFFENBURG, BAVARIA.

THE TRANSLATION REVISED BY

S. H. VINES, M.A., D.Sc., F.L.S.,
FELLOW AND LECTURER OF CHRIST'S COLLEGE, CAMBRIDGE.

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SECOND EDITION, GREATLY REVISED.

LONDON:
W. SWAN SONNENSCHEIN & ALLEN,
PATERNOSTER SQUARE.
1881.

Butler & Tanner,
The Selwood Printing Works,
Frome, and London.

PREFACE TO THE ENGLISH EDITION.

This book was written by Prof. Prantl to meet a growing demand for a work on Botany, which, while less voluminous than the well-known "Lehrbuch" of Prof. Sachs, should resemble it in its mode of treatment of the subject, and should serve as an introduction to it. That it has not failed in this object is shown by the fact of its having already reached a third edition. It is hoped that this English Edition will as adequately supply the want of a work of this kind which has long been felt in this country.

In preparing this edition for publication, I have felt that the main object was the production of an accurate and intelligible translation, and I have therefore made but few alterations in the Author's text. I have ventured, however, to introduce the General Classification of Thallophytes (page 110) proposed by Prof. Sachs in the fourth edition of his "Lehrbuch," for I am of opinion that this mode of regarding the Thallophytes is a considerable assistance to the student. In consequence of this I have arranged the various families of Thallophytes in an order which is slightly different from that followed by Prof. Prantl.

Further, I have not designated the decomposition of carbonic acid and water by the chlorophyll under the influence of light, by the term "assimilation," as is usually done. This term has already a well-defined meaning in Physiology, and it is therefore a mistake to re-introduce it in another sense. At the same time I do not feel myself quite in a position to suggest a term to replace it.

S. H. V.

CAMBRIDGE, *March*, 1880.

PREFACE TO THE SECOND ENGLISH EDITION.

I have ventured, in the preparation of this edition, to make considerable alterations in the book, with the view of increasing its usefulness. For these I am alone responsible. Many of them have been made at the suggestion of friendly critics, known and unknown, and for this kind assistance I would here express my thanks. The most important alteration is the adoption of a Classification of Flowering-Plants which will be more familiar to English students than that which was followed in the First Edition.

S. H. V.

CAMBRIDGE, *April*, 1881.

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PART I.

THE MORPHOLOGY OF PLANTS.

§ 1. **The Members of the Plant.** An ordinary flowering-plant consists of a number of parts which are distinguished as roots, stems, leaves, fruits, etc. These may be considered scientifically in two ways; either with reference to their functions in the economy of the plant, when they are regarded as the *organs* by which these are performed, and are the subjects of *physiological* study; or, their functions being disregarded, their relative position, the place and mode of their origin, the course of their growth, and their relative size may be considered; that is, they may be studied from a purely *morphological* point of view, when they are regarded merely as parts of a whole, and are designated as *members*. The members may be conveniently arranged in four categories, namely, *Roots*, *Stems* (Caulomes), *Leaves* (Phyllomes), and *Hairs* (Trichomes). When the body of a plant does not present any differentiation into root, stem, and leaf, as in the case of the Algæ and Fungi, it is termed a *Thallus* (Thallome).

With the exception of the primary axis of the seedling, all members are developed laterally upon others, which may or may not belong to the same category. A root, for example, is repeatedly producing lateral roots which are similar to each other and to the main root from which they have arisen; a stem, on the other hand, produces, in addition to branches which are similar to itself, leaves and roots. Every member remains in connection by its organically lower end, its *base*, with the member from which it has been developed: the opposite end is the organically upper end or *apex*. Those members, viz., stems and roots, which more especially produce lateral members, continue to grow at their apices, and the lateral members are normally developed behind the apex in such a way that the youngest of them lies nearest to the apex. Thus, the youngest lateral root is the nearest to the apex of the mother-root, and it is the youngest leaf which is the nearest to the apex of the stem; hence in all normally developed members the succession in time may be inferred from the succession in space; that is to say, in counting the leaves on a stem from the base upwards, the order of their succession in space denotes the order of their development. All lateral members which are thus arranged are said to have originated in *acropetal succession*. When in any cross section of the parent member not one only, but two or more lateral members, occur at the same level, this mode of arrangement is termed a *whorl;* for instance, of secondary roots round a parent-root, or of leaves round a stem, as in Herb Paris (*Paris quadrifolia*). Those members which lie at the same level and form a whorl may be developed simultaneously, or one after the other; hence a whorl may be *simultaneous* or *successional*. In the latter case it is more difficult to distinguish the acropetal succession as well of the whorls as of their individual members. Those members are said to be *adventitious* which are not developed at the growing point but on older parts, and which are therefore not arranged in acropetal succession; for instance, those lateral roots which are developed from older ones, and many branches from old stems. The formation of lateral members may either take place *exogenously*, in which case they originate from the outer layers of tissue of the parent-member, as leaves do from that of the stem (Fig. 1), or *endogenously*, in which case they are formed from the internal tissue of the parent-member and have to penetrate its outer layers; it is in this latter manner that roots are developed either from older roots (Fig. 20) or from stems.

§ 2. **Of the Leaf and Stem in general.** These two ideas are so intimately connected that it is impossible to think of one without the other, as is evident from the following definitions:

Every part of a plant which produces leaves at its growing end is called a *Stem* or *Axis;* a stem, together with the leaves it bears, is known as a *Shoot:*

Leaves are distinguished by the following characters. 1, They originate always in acropetal succession (they are therefore never adventitious); 2, they are always exogenous; and 3, they always assume a form different from that of the stem and its lateral branches upon which they are borne.

The leaves are developed in very close apposition at the apex of the stem. The portions of the stem, termed *internodes*, which lie between the individual leaves may either remain quite short, as in the case of the rosette of leaves of the Plantain and of the House-leek, of the fascicled leaves of the Larch, and in most flowers; or they may undergo a considerable elongation so that the leaves become widely separated. The boundaries of the internodes—the places, that is, at which the leaves are inserted—termed *nodes*, are sometimes prominently developed, more particularly when the leaves are arranged in whorls, *e.g.*, Labiatæ, or when they ensheath the stem. The portion of the surface of the stem from which the leaf arises is the *insertion* of the leaf, and its organic centre is called the *point of insertion*. After the fall of the leaf the surface where it was inserted remains for a long time visible as a *scar* or *cicatrix*.

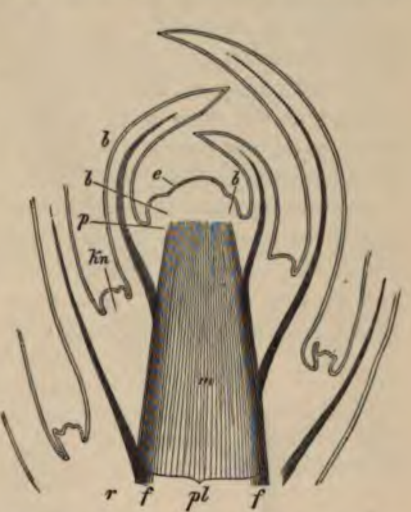

FIG. 1.—Diagrammatic longitudinal section through the growing apex of a stem; *b* the leaves; *kn* their axillary buds; *e* epidermis; *f* fibrovascular bundles.

So long as the internodes have not begun to elongate, and the leaves are still folded together so as to cover the apex of the stem, the growing end of each shoot is known as a *bud*. The bud which lies at the apex of a shoot, the lower portion of which has already undergone elongation, is a *terminal bud*; the *lateral buds* are the early stages of shoots developed laterally upon a growing main shoot, which often remain in this condition for a considerable time. The arrangement of the lateral buds, and consequently that of the branches which are developed from them, is closely related to that of the leaves; thus in Mosses and many Ferns they are developed immediately below or by the side of a leaf; in the higher plants, always in the *axil* of a leaf, that is to say, in the angle made by a leaf with the internode above its insertion. In the latter case they make their appearance at the first formation of the leaves (Fig. 1, *kn*). With few exceptions, they are developed in the axil of every leaf, the exceptions being the leaves that form the flower, and those of many of the Conifers.

§ 3. **The Arrangement of the Leaves** (Phyllotaxis). The arrangement of the leaves on the stem is most intimately connected with the acropetal order of their development; and since, as has been already shown, the arrangement of the lateral shoots depends on that of the leaves, the same laws determine the arrangement of both these sets of members which apply generally to all acropetally developed members of plants. These laws are most conspicuously exhibited in the arrangement of the leaves, and they will be fully discussed with reference to these members only.

Leaves are developed either in *whorls*, that is to say, two or more at the same level on the stem, or singly, when their arrangement is said to be *scattered*. In some cases certain of the internodes do not elongate, and therefore the leaves, which have been really developed singly, or their axillary buds, appear to have been developed at the same level on the stem, thus forming a *spurious whorl*, as in the case of the upper leaves of the Tiger-lily and of the whorled branches of the Pines.

The arrangement of the leaves on the circumference of the stem is also very variable; this is particularly conspicuous in the cases where the leaves are arranged in whorls, for which reason these will be first discussed. If a whorl consists, for instance, of two leaves, it is obvious, that they will be placed exactly opposite to each other on the surface of the stem, and that the distance between them, measured from the points of insertion, will amount to just half the circumference of the stem. Similarly, if the whorl consist of three leaves, the distance between any two adjacent leaves will be one-third of the circumference, and so forth. The lateral distance between the points of insertion of two adjacent leaves, measured on the circumference of the stem, is called their *divergence*, and it is expressed in fractions of the circumference.

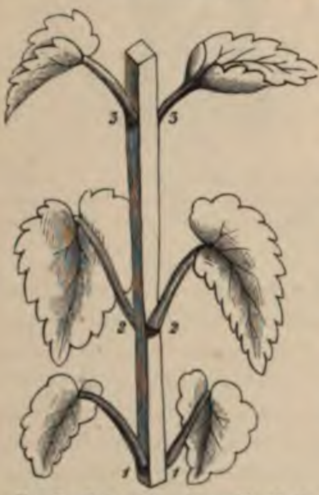

FIG. 2.—Stem of Lamium with whorls of two leaves; 1-1, 2-2, 3-3, the successive whorls.

Moreover, it is a rule, though not without exceptions, that the successive whorls alternate, so that the leaves of any whorl lie opposite to the intervals between the leaves of the whorls above and below it. Thus the leaves of alternate whorls are exactly above each other (Fig. 2).

This arrangement, as in fact all relations of position, may be very plainly exhibited by means of diagrams (*e. g.*, Figs. 3 and 4). Such a diagram consists of a ground-plan of the stem, regarded as being a cone, and looked at from above: the insertion of each leaf will lie upon one of a series of concentric circles, and the higher the insertion of the leaf upon the stem, the nearer to the centre will be the circle of the diagram upon which its insertion is indicated.

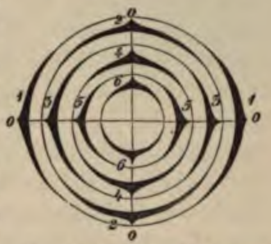

FIG. 3.—Diagram of a Stem with alternate two-leaved whorls. 0, 0, 0, 0, the four orthostichies. 1,1, 2,2, 3,3, the successive whorls.

It may be perceived in the diagram Fig. 3, that when the leaves are arranged in alternate whorls they form twice as many longitudinal series on the stem as there are leaves in each whorl, provided, of course, that the number of leaves in each whorl is the same. The longitudinal series, which are indicated in the diagram by radii, are called *orthostichies.*

This particular arrangement of alternate whorls of two leaves occurs very frequently, and is termed the *decussate* arrangement. The two leaves of each whorl are said to be *opposite.* It is comparatively rare for equal successive whorls to be *superposed;* that is, that the leaves of each whorl should lie exactly above or below those of the others, so that there are only as many orthostichies as there are leaves in each whorl.

Examples of decussate leaves: the Caryophyllaceæ, the Labiatæ, the Caprifoliaceæ, to which belong Syringa (Lilac), Lonicera (Honeysuckle), and Sambucus (Elder); the Maple, the Horse-chestnut, and the Ash. In *Rhamnus catharticus* the two leaves of each whorl are usually at a slightly different level.

Alternate whorls of 3 (irrespectively of flowers) occur in the common Juniper, in Catalpa, and occasionally in the Horse-chestnut and the Maple.

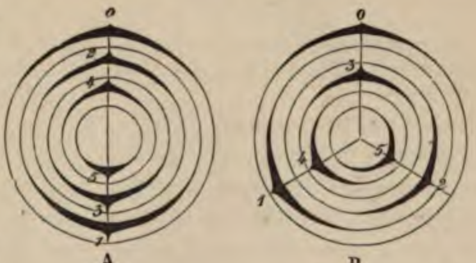

FIG. 4.—*A.* Diagram of a stem bearing leaves with a divergence of ½. *B.* A stem bearing leaves with a divergence of ⅓.

When the leaves are arranged in a scattered manner it is easy to detect that, within a certain region of the stem, their divergence is constant; that is, that the distance between any leaf and its immediate predecessor and successor is a certain fraction of the circumference. In the simplest case, when the divergence is $\frac{1}{2}$ (Fig. 4 A), starting with any leaf 0, the insertion of the next leaf in succession on the stem, which may be numbered 1, will be exactly opposite to that of the leaf 0, and the next leaf, numbered 2, will be opposite to 1 and exactly above 0. Thus there are two orthostichies. In proceeding from leaf 0 to 1, 2, 3, and so on, always in the same direction, the circumference of the stem is traversed in a spiral which, in the course of each whole turn, touches the bases of two leaves and intersects the same orthostichy. This spiral will pass through the insertion of every leaf, and as it does so in the order of their development, it is known as the *genetic spiral*. The number of leaves through which the genetic spiral passes in its course between any two on the same orthostichy is termed a *cycle*. When the divergence is $\frac{1}{3}$, the leaf numbered 3 comes exactly above leaf 0; 4 over 1, 5 over 2; and so on; and there are three orthostichous lines, the cycle being composed of three leaves. It might be said with equal accuracy that the divergence is $\frac{2}{3}$, since leaf 1 is distant $\frac{2}{3}$ of the circumference from leaf 0, if the spiral be followed in the other direction. If it be continued in this direction, it will pass round the stem twice in each cycle. For the sake of simplicity, the spiral is not traced in this longer way, but in the shorter way. When the numerator of the fraction of divergence is not 1, but some other rational number, the spiral passes round the stem more than once within the cycle, in fact, just as many times as is expressed by the numerator of the fraction of divergence; the denominator of the fraction expresses the number of the orthostichies. In Figs. 5 and 6, which represent a constant divergence of $\frac{3}{8}$, it is easy to see that eight orthostichies are present, leaf 9 being over 1, 10 over 2, and so on; also that the spiral returns to a leaf on the same orthostichy after three turns, and thus goes thrice round the stem in one cycle.

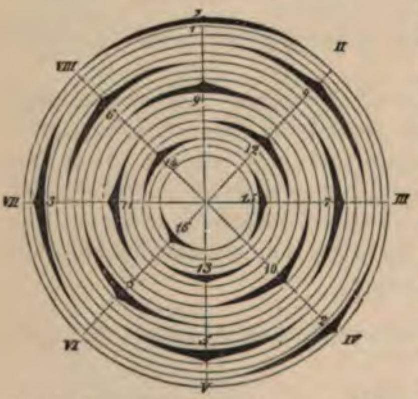

FIG. 5.—Diagram of a stem with a constant divergence of $\frac{3}{8}$. I, II, III, etc., the orthostichous lines. (After Sachs.)

If it is required to determine the arrangement of the leaves (phyllotaxis) on a stem, it is necessary to find the leaf which is exactly above the one, numbered 0, selected as a starting-point, and then to count the number of leaves which are met with in following the shorter spiral round the stem between these two leaves. The number of the leaf which lies in the same orthostichy is the denominator of the fraction of divergence, and the numerator is the number of turns made by the spiral between the two leaves.

When the number of orthostichies is greater than 8, it becomes very difficult to detect them, particularly when the leaves are closely arranged as in the rosette of the House-leek, the capitulum of the Sunflower, or as the scales in a Fir cone. Another set of lines lying obliquely then strike the eye, called *parastichies*, which also run round the stem in a spiral, but touch only some of the leaves; for instance, in Fig. 6, the line which connects the leaves 3, 6, 9, and 12. It is evident that the number of parallel parastichies must be as great as the difference between the numbers of the leaves in any one such line. Thus in Fig. 6, again, another parastichy connects the leaves 2, 5, 8, 11, and so on; and a third, the leaves 1, 4, 7, 10, etc. From this it is possible to deduce a simple method for ascertaining the phyllotaxis in complicated cases: the parastichies which run parallel in one direction are counted, and the leaves in one of them are numbered according to the above-mentioned rule; by repeating the process in another system of parastichies which intersects the first, the number of each leaf will be found.

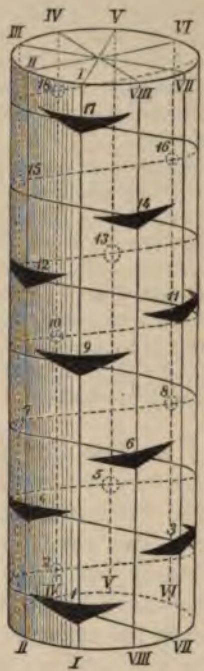

FIG. 6.—Diagram of a stem the leaves of which have the constant divergence of $\frac{3}{8}$; the leaves of the anterior surface are indicated by their insertions, those of the posterior by circles; they are connected by orthostichies. I, I, II, II, etc., are the eight orthostichies.

The commonest divergences are the following:

$$\frac{1}{2}, \frac{1}{3}, \frac{2}{5}, \frac{3}{8}, \frac{5}{13}, \frac{8}{21}, \frac{13}{34}.$$

This series is easy to remember, for the numerator of each fraction is the sum of those of the two preceding, and it is the same with the denominators.

There are, however, divergences which are not included in this series, *e.g.*, $\frac{1}{4}$, $\frac{2}{7}$, $\frac{2}{9}$, etc. In some cases the construction of a spiral with a constant divergence is impossible, as in Salvinia.

The causes of this regularity of arrangement of the leaves lie partly in the mode of origin of the leaves at the apex of the stem and partly in the displacements which they undergo in the course of their subsequent growth.

Instances of the divergence $\frac{1}{2}$: all Grasses, and the smaller branches of the Elm, the Lime, the Hornbeam, and the Beech; in these, particularly in the last, the leaves undergo displacement, so that on the under side of the branch the divergence is less, and the upper side it is greater than $\frac{1}{2}$.

Divergence of $\frac{1}{3}$ is found in all the Sedges, and in the branches of the Alder and Aspen.

Divergence of $\frac{2}{5}$ may be regarded as the most frequent; it occurs in many herbaceous plants and in most of the smaller branches of the Willow, the Poplar, the Oak, the Rose, the Cherry, and the Apple.

The acicular leaves of the Firs and Spruces usually have a divergence of $\frac{3}{8}$ and $\frac{5}{13}$: $\frac{8}{21}$ occurs very commonly in the cones.

Finally, it may be observed that the genetic spiral turns sometimes to the right and sometimes to the left on the stem: in botanical terminology, a spiral is said to be right-handed when it runs in such a direction that if the observer ascended along it he would have the axis on his right; and left-handed, when it runs in the contrary direction.

§ 4. The Form of the Mature Leaf.

A leaf is usually flattened horizontally into a broad surface; it is thin, and of such a form that it can be divided by a perpendicular plane, the *median plane*, into two similar halves. The halves are usually counterparts, like the right and left hand, or an object and its reflected image; the leaf is then said to be *symmetrical*. *Unsymmetrical* leaves, the halves of which are not similar, occur in the Elm, and very conspicuously in Begonia. The lower or outer surface of the leaf usually differs from the upper or inner surface in structure, colour, hairiness, etc. As a rule the surface of the leaf is extended at right angles to the median plane, and also to the longitudinal axis of the stem; but this original position is frequently altered by subsequent torsions. Decussate leaves, for instance, are often so twisted that the upper surfaces of all of them come to lie in one plane, as in Philadelphus; and on the horizontal branches of the Silver Fir the leaves that grow on different parts of the stem are so twisted that their upper surfaces are all directed towards the zenith. Rarely, as in the Iris, the leaf is from the first extended in the median plane itself.

Departures from the ordinary flattened form of the leaf are found in the acicular leaves of the Spruce, in the cylindrical leaves of many species of Sedum and Mesembryanthemum, and in the tubular leaves of Allium and Juncus.

The leaf is usually regarded as consisting of three parts: the *sheath*, the *stalk*, and the *lamina* or *blade*. The *sheath* (Fig. 7 *v*) encloses the stem at the insertion of the leaf, assuming a tubular or sheath-like form; it is largely developed in Grasses and Umbelliferæ. The *leaf-stalk* or *petiole* (Fig. 7 *p*) is narrow, usually semi-cylindrical or prismatic in form, and bears at its end the expanded blade (Fig. 7 *l*): occasionally, as in the Australian Acacias, it is flattened and leafy, when it is termed a *phyllode*. These three portions are not, however, developed in all leaves. Many leaves, as those of the Maple and the Gourd, have only petiole and blade; others, as the Grasses, only sheath and blade. Frequently the blade only is present, as in the Tobacco and the Tiger-lily, when the leaf is said to be *sessile*.

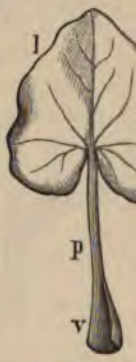

FIG. 7.—Leaf of *Ranunculus Ficaria*. *v* Sheath; p stalk; *l* blade (nat. size).

The *stipules* must be regarded as belonging to the sheath: when they are present the leaf is said to be *stipulate;* but they are frequently wanting, and the leaf is then said to be *exstipulate*. In many plants they take the place of the sheath and appear as two outgrowths at the base of the leaf (Fig. 8 *B* and *C s s*). They are often similar in colour and texture to the leaves, as in Willows, Peas, the Violet, and the Rubiaceæ, in which they are compound; in other plants, on the contrary, they are colourless or brown, and fall off soon after the leaf is unfolded, as in the Beech, the Elm, and the Lime. Sometimes a pair of stipules occur as well as a sheath, and they appear as teeth at the top of the sheath, as in the Rose. Occasionally the two stipules are *connate*, that is, they are more or less united: when they cohere by their outer margins they form an *opposite* stipule, as in Astragalus, and when they cohere by their inner margins they form an *axillary* stipule, as in *Houttuynia cordata:* in the Polygonaceæ they cohere by both their inner and outer margins, thus forming a sheath, termed an *ochrea* (Fig. 207 A *o*) which surrounds the internode above the insertion of the leaf: when the stipules of opposite leaves cohere they form what are termed *interpetiolar* stipules, as is frequently the case in the Rubiaceæ.

Only in comparatively few plants does a *ligule* occur; this is a small outgrowth from the upper (inner) surface of the leaf, which is found in the Grasses at the junction of the sheath and the blade (Fig. 8 *A i*), and also in the petals of many flowers, as Lychnis and Narcissus.

In the case of most leaves it is obvious that their internal tissues are differentiated. The fundamental tissue, which is generally green, the *mesophyll*, is traversed by bright bands, which are the fibro-vascular bundles or so-called *veins*. These usually project on the under surface, and when the leaf decays, remain for a time as a skeleton of the leaf. The distribution of these bundles, the *venation*, is characteristic of large groups of plants. In the narrow leaves of most of the Monocotyledons the veins are parallel, branching rarely or not at all (Fig. 13 *L*), and they are therefore said to be *parallel-veined;* while in many of the Dicotyledons only a few veins enter the leaf, which branch frequently and anastomose, forming a *reticulated* venation. According to the ramification of the veins, the venation may be either *pinnate* (Fig. 9 *A*), that is to say, a median vein or mid-rib runs through the leaf and gives off several lateral branches, as in the Tobacco, Beech, and Elm; or it may be *palmate* (Fig. 9 *B*), that is, the vein divides at its entrance into the lamina into a number of equal diverging veins, which may again divide, as in the Maple and Ivy.

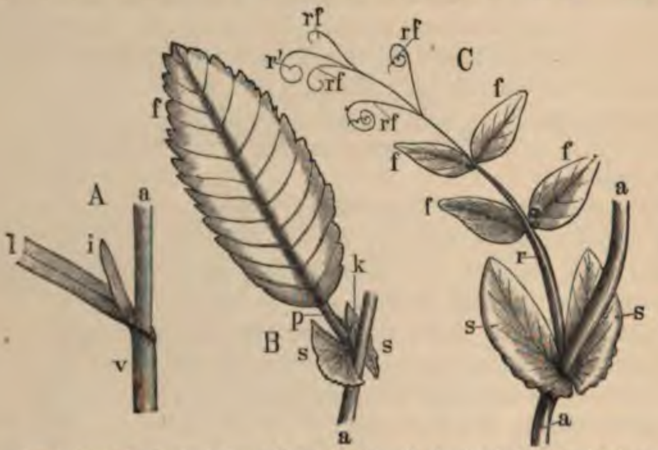

FIG. 8.—*A* Part of a leaf of Grass (*Poa trivialis*) with the ligule *i*; *a* the haulm; *v* the sheath; *l* lamina of the leaf. *B* Leaf of a Willow (*Salix Caprea*); *a* stem; *s s* stipules; *p* petiole; *f* lamina; *k* axillary bud (nat. size). *C* Leaf of a Pea (*Pisum arvense*); *a* stem; *s s* stipules; *r* rachis; *f f* leaflets; *rf rf* the upper leaflets metamorphosed into tendrils; *r'* end of the rachis, likewise transformed into a tendril.

In descriptive Botany a number of terms are used to describe the details of the insertion, the contour, the apex, margin, and the segmentation of leaves. The most important are as follows:

When the blade springs immediately from the stem the leaf is said to be *sessile; amplexicaul,* when it surrounds the whole, *semi-amplexicaul,* when it surrounds only half of the circumference of the stem at its insertion (Fig. 10 *A. Thlapsi perfoliatum*); *perfoliate,* when the two opposite margins of the base of the leaf meet and coalesce on the opposite side of the stem from the point of insertion, *e.g., Bupleurum rotundifolium* (Fig. 10 *B*). This form must not be confounded with *connate* leaves, in which case two leaves growing at the same level on opposite sides of the stem unite at their bases, *e.g.,* the Honeysuckle (*Lonicera Caprifolium,* Fig. 10 *C*).

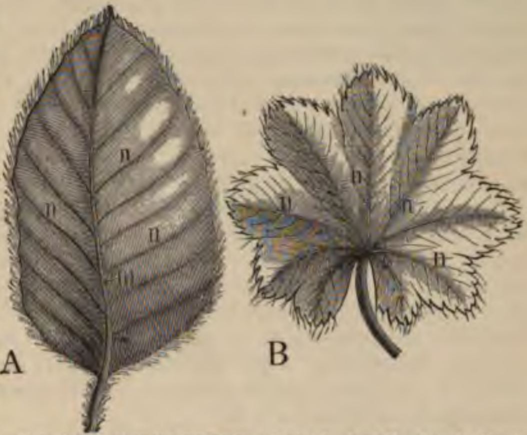

FIG. 9.—*A* Pinnate venation of the leaf of the Beech, *Fagus sylvatica; m* mid-rib, *n* lateral veins; *B* Palmate venation of the leaf of *Alchemilla vulgaris* (nat. size).

In *decurrent* leaves leafy wings extend downwards from the insertion along the stem, which is then said to be *winged, e.g.,* many kinds of Mullein (Verbascum); and the leaf-stalk is sometimes winged in the same way by a downward growth of the lamina.

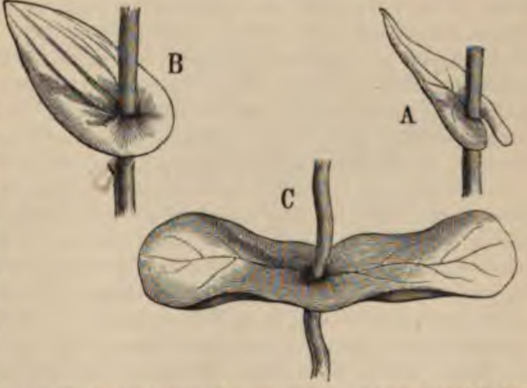

FIG. 10.—The insertion of sessile leaves. *A* amplexicaul leaf of *Thlapsi perfoliatum. B* perfoliate leaf of *Bupleurum rotundifolium. C* connate leaves of *Lonicera Caprifolium.*

The petiole is occasionally inserted on the under side of the blade, which is then said to be *peltate;* but it is usually inserted at its lower edge, and is either sharply defined from it or gradually merges into it; an example of this latter mode is afforded by the *cuneiform* leaves of the Daisy (*Bellis perennis*). A *heart-shaped* or *cordate* leaf is one of which the lower edge is deeply hollowed in the median line, whether it be sessile or stalked, *e.g.*, the Lilac (Syringa). It is *arrow-shaped* or *sagittate*, when the blade is much prolonged on each side of this hollow, as in the Arrow-head (Sagittaria). As to the general form of the leaf, it said to be *linear* when the opposite edges are nearly parallel, *e.g.*, in Grasses; *lanceolate*, when the leaf is at least four times as long as it is broad, *e.g.*, the Rib-wort (Plantago); *elliptical*, when the leaf is about twice as long as it is broad, *e.g.*, the leaflets of the Rose; *ovate*, when the leaf is at the same time broadest towards the base; *obovate*, when it is broadest towards the apex; *subrotund*, *orbicular*, *reniform*, when it is both broad and somewhat heart-shaped, *e.g.*, Ground Ivy (Glechoma) (Fig. 14 *E f*).

The leaf is also described, according to the form of the apex of the blade, as being *acute*, when the lateral margins gradually converge at an acute angle, *e.g.*, the Rib-wort; as *acuminate*, when the apex tapers rapidly (Fig. 11 *G*), *e.g.*, the separate leaflets of the Horse-chestnut; or as *obtuse* or as *emarginate* (Fig. 11 *D f′*), when it is more or less indented at the broad obtuse apex, as in some kinds of Senna (*Cassia obovata*); as *obcordate*, when this indentation is deeper, as in the leaflets of the Woodsorrel (Oxalis); and as *mucronate*, when there is a sharp projection from the obtuse apex, as in the leaflets of Lucerne (*Medicago sativa*) (Fig. 11 *F f′ s*).

The margin of the leaf is either *entire* (Fig. 13 *L*), as in the Forget-me-not and Tulip; or it presents slight asperities, when it is said to be *dentate* (as in each segment of the leaf in Fig. 11 *C*); or it is sinuous, with sharp spines, as in the Holly (*Ilex Aquifolium*), when it said to be *wavy;* or it is *serrate*, with teeth directed towards the apex (Fig. 9 *B*), as in the Rose; or *crenate*, with obtuse indentations, as in the Violet (Fig. 14 *E f*). If the margin be more deeply indented, the leaf is said to be *incised*, and the incision may be either *palmate* or *pinnate*, according to the mode of venation. In order to express the fact that the incision extends less or more nearly to the junction of the lamina and petiole in palmate leaves, or to the mid-rib in pinnate leaves, different terms are used. Thus the leaf is said to be *lobed* and *pinnatifid* or *palmatifid*, when the incision does not extend so far as half way (in a palmate leaf, Fig. 9 *B*); *partite*, when it extends about half way (Fig. 11 *A*); *dissected*, when it extends the whole way (pinnatisected, Fig. 11 *C*).

Compound leaves are formed by the division of the lamina into several smaller laminæ, connected by their secondary petioles (*petiolules*), which are called *leaflets* (foliola) (Fig. 11 *f′*). The compound leaf, like the lobed or partite simple leaf, may be palmate or pinnate. In the former case it is called, according to the number of the leaflets (three, four, five, or more) *ternate*, *quadrinate*, *quinate*, etc. (Fig. 11 *B* is ternate), and by further division of the leaflets it may become *biternate* or *triternate*, etc. (*e.g.*, Clover, Lupin, Horse-chestnut). In the *compound pinnate* leaf the separate leaflets are called *pinnæ*, and are inserted on each side of the mid-rib, or *rachis* (Fig. 11 *B f′*), which appears to be a prolongation of the true petiole (Fig. 11 *D r*). If the rachis terminates in a single leaflet, the leaf is said to be *imparipinnate* (Fig. 11 *D t*); but when it has no terminal leaflet, it is *paripinnate* (Fig. 11 *E*). According to the number of the pairs of leaflets, the leaf is said to be *bi-* or *tri-jugate*, etc.

(Fig. 11 *E*). It is *interruptedly pinnate* when large and small pinnæ occur alternately or irregularly, as in *Potentilla anserina*. When the pinnate segmentation is repeated, the leaf becomes *bi-pinnate* or *tri-pinnate* (Fig. 11 *H*). Many leaves, by a combination of palmate and pinnate arrangement, acquire a highly complex conformation, as is seen in many umbelliferous plants.

Leaves or portions of leaves are occasionally transformed into *tendrils*, which are organs of attachment (see § 48); this is the case with the rachis and with

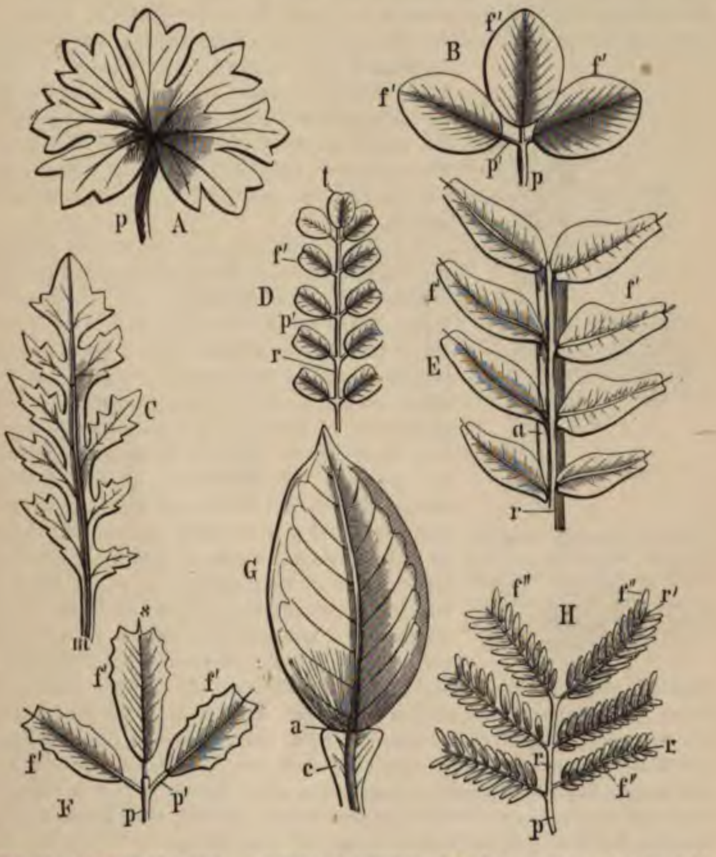

FIG. 11.—Incision of leaves. *p* petiole; *p'* petiolule; *f'* leaflet; *r* rachis. *A* Palmatifid leaf of Geranium. *B* Ternate leaf of Clover. *C* Pinnatisected leaf of *Papaver Argemone*. Compound leaves; *D* Imparipinnate, *Hippocrepis comosa*: *t* terminal leaflet. *E* Pari-pinnate, *Pistacia lentiscus*; *a* wing of the rachis. *F* Imparipinnate unijugate leaf of Medicago. This differs from *B*, which is ternate, inasmuch as the secondary leaf-stalks *p'* do not all spring from one point, but the common leaf-stalk *p* extends beyond the insertion of the single pair of pinnæ. *G* Leaf of the Orange; the articulation *a* between the blade and the winged petiole shows that it is a compound leaf. *H* Bipinnate leaf of the Acacia; *r'* secondary rachis; *f''* secondary pinnæ.

all or some of the pinnæ, in the Vetch, Pea, and other allied plants (Fig. 8 *C r′* and *rf*). Less frequently the lamina is metamorphosed into an *ascidium*, assuming the form of a pitcher, as in Nepenthes.

The texture of most leaves may be described as *herbaceous*. Leaves of this kind last usually for only a single season, and die or fall off in the autumn. Leaves of firmer texture, which are said to be *coriaceous*, survive the winter, and either fall off when the new leaves are developed (the Privet), or continue to live for several years, (Holly, Box, and most Conifers; the acicular leaves of the latter may persist for as many as twelve years, (Silver Fir)). *Fleshy* or *succulent* leaves occur in Aloe, Sedum, etc. In many cases leaves are metamorphosed into *spines:* these are hard-pointed, woody structures, which, from their position, may be recognised as being modified leaves; such are the leaves on the shoots of Berberis (Fig. 12 *a b*), the stipules of *Robinia Pseudacacia*, the persistent petioles of many species of Caragana and Astragalus.

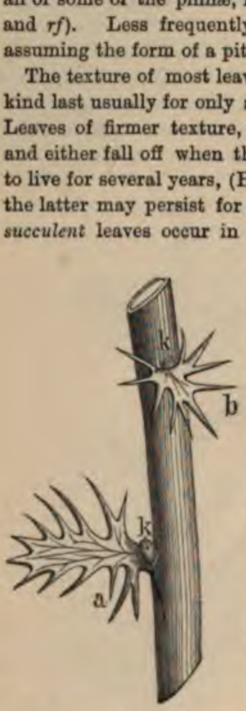

FIG. 12.—Leaf-spines of *Berberis vulgaris*, at the base of a shoot of one year's growth. *a* leaf-spine with broad surface; *b* with a smaller surface; *k k* axillary buds (nat. size).

The relative position and the form of leaves in the bud present many characteristic peculiarities.

According to the greater or less breadth of the leaves, those which are contiguous to each other either merely touch at their edges (*valvate prefoliation*, or *æstivation* in the case of flowers), or their edges overlap (*imbricate prefoliation*); an intermediate form, known as the *contorted* or *twisted*, is to be found, for example, in the arrangement of the petals of the Periwinkle; in this case one margin of each leaf is directed obliquely inwards, and covers that of the next. As regards the form of the individual leaves in the bud, called the *vernation*, it is distinguished as *plane*, when the leaf is not folded; as *conduplicate*, when the two halves of the leaf are folded inwards from the midrib (*e.g.*, the Bean); as *plicate*, when the leaf is folded in numerous longitudinal or slanting pleats (*e.g.*, the Beech); as *crumpled*, when the foldings and inequalities are in every direction (*e.g.*, the petals of the Poppy); as *involute*, when the edges are rolled inwards towards the midrib (*e.g.*, the Violet); as *revolute*, when they are rolled inwards towards the midrib on the lower surface (*e.g.*, Sorrel); as *convolute*, when the whole leaf is rolled up from one margin so as to form a single coil (*e.g.*, Canna); or as *circinate*, when the leaf is rolled up from the apex downwards (*e.g.*, Ferns).

In highly organised and differentiated plants many forms of leaf-structures (phyllomes) may be distinguished, for certain regions of the stem bear peculiar forms of leaves, which though differing in some respects, agree in their general characteristics. These are:

1. *Foliage leaves*, usually known simply as leaves (Fig. 13 *L*). This is the most general form. These leaves are conspicuous on account of their green colour, and in accordance with their function (see § 33), they are exposed as much as possible to the sun-light. If they are small they are very numerous (Conifers), and the larger they are the fewer they are (Sun-flower, Paulownia). They always possess a well-developed lamina, which presents the various peculiarities of form previously described.

2. *Scales* or *cataphyllary leaves* (Fig. 13 *N*). These are usually of a yellow or brown colour, of simple structure, without projecting veins, and attached to the stem by a broad base. They may be regarded as the sheaths of leaves, the petioles and laminæ of which have not been developed; this is true even in the case of those plants the foliage-leaves of which usually develope no sheaths. They always occur on subterranean stems (*e.g.*, the scales of the Onion), and sometimes on aërial stems. Many plants which are not green (Orobanche, Neottia) produce only cataphyllary leaves in addition to the floral organs. The most common form in which they occur upon aërial stems is that of scales investing the buds of trees. In this case they are the lowest leaf-structures borne by the annual shoot, and usually fall off as the bud developes.

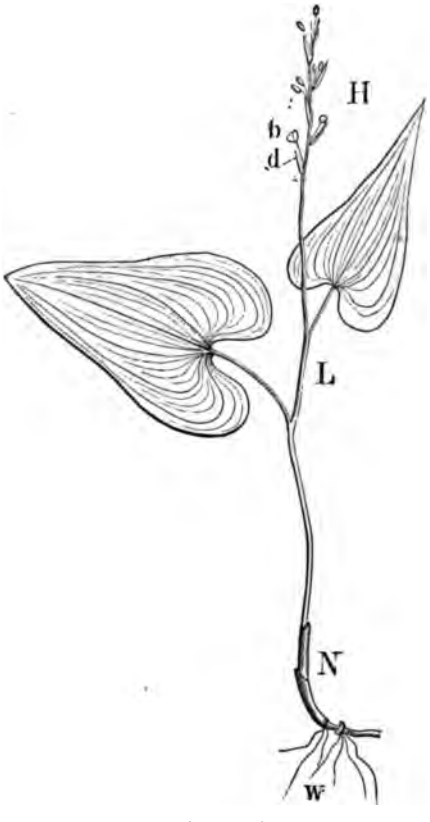

FIG. 13.—The three forms of leaves on the stem of *Maianthemum bifolium* (nat. size); *N* the scales; *L* the foliage leaves; *H d* the bracts; *b* the flowers in their axils; *w* roots.

Some indigenous trees have naked buds without scales, as *Viburnum Lantana* and *Rhamnus Frangula*. The following varieties of bud-scales may be distinguished:

a. No true bud-scales—the investment of the bud is formed by the stipules of the first foliage-leaf: *Alnus incana* and Liriodendron.
b. The stipules possess laminæ, and are covered externally by one or more simple scales: Poplar, Willow, Elm.
c. The bud-scales are stipules without laminæ: within them are stipules with laminæ, and there may be simple scales outside of them: Beech, Oak (or they may be absent), Birch.
d. The bud-scales are simple leaf-sheaths without laminæ; the foliage-leaves possess neither stipules nor sheaths; Abietineæ, Maple, Horse-chestnut.

In a certain sense the *cotyledons* of Phanerogams, the leaves first developed from the seed, may be regarded as cataphyllary leaves. These will be discussed at a later period.

3. *Hypsophyllary leaves* or *bracts* (Fig. 13 *Hd*) belong to that region of the stem which bears the flowers. They are smaller than the foliage-leaves, and are inserted upon the stem by a narrow base (the glumes of Grasses). They may be green or of various colours.

4. The *Flower* is a shoot, the leaf-structures of which have been modified into sepals, petals, stamens, and carpels. It is peculiar to Phanerogams, and will be discussed when those plants are treated of. (Part IV.)

§ 5. **Stem-structures or Axes** (Caulomes), with the exception of the primary stem of the seedling, which is derived directly from the oosphere, take origin from stems of older growth; they usually spring, as has been shown in § 3, from the axils of the leaves. As a rule, one lateral shoot is formed in the axil of each leaf, but sometimes more than one is formed; when this is the case, the shoots are either situated one above the other, as in Gleditschia, or side by side, as in the bulbs of Muscari. All the shoots that originate as lateral buds are not necessarily developed into branches; thus the buds which are formed in the axils of the bud-scales always remain undeveloped, and are only incited to growth when the other buds are destroyed. Buds which thus remain undeveloped for a long period, often for years, are called *dormant*, and the shoots which are ultimately produced from them are said to be *deferred*.

Adventitious shoots occur on old stems, and also on roots; frequently, for instance, on those of the Poplar; sometimes even on leaves, as in Bryophyllum and many Ferns.

Buds which become separate from the parent plant before their elongation has begun, and produce new independent plants, are called *bulbils;* such are the bulbous buds in the axils of the leaves of *Lilium bulbiferum*, and in the inflorescences of species of Allium, etc.

The typical form of the stem is cylindrical or prismatic; in the latter case the number of the angles bears a definite relation to the arrangement of the leaves; for instance, when the leaves are opposite and decussate, the stem is quadrangular. Irrespectively of the the thickenings of the stem at the nodes which separate the internodes, a tumidity, the *pulvinus*, usually occurs at the insertion of the leaf, which is very conspicuous on the branches of the Fir, Poplar, and Ash.

The different forms of stems are determined by the period and direction of their growth, the length of their internodes, the relation of their thickness to their length, the form of the leaves they bear, and by other factors.

The soft herbaceous axis of annual plants is usually known as a *stalk* (caulis); the terms *trunk*, *branch*, and *bough* are usually applied to stem-structures which persist and increase in thickness for several years. The latter are built up of successive annual shoots; for, during the time when growth is inactive, which in our climate is in the winter, the apical and the lateral shoots remain quiescent in the condition of buds. The lowest internodes of each annual shoot are short, particularly those which lie among the bud-scales, so that the limit between the shoots of two successive years is easily recognised even in old branches by the close arrangement of the scars of the fallen bud-scales. The other internodes of the annual shoot are longer nearer the apex, but are sometimes short again close beneath it, as in the Oak, so that the leaves and lateral buds are crowded below the terminal bud. When most of the internodes are elongated, as has been described, the structure in question is an ordinary shoot: but on many trees there are also *dwarf-shoots*. These are annual shoots the internodes of which have hardly elongated at all, and usually bear no lateral shoots; such are the shoots bearing the fascicled leaves of the Larch, which spring from the axils of the leaves of an ordinary shoot of the same year: they usually elongate but slightly each year, but shoots of this description may, under certain circumstances, develope into ordinary shoots. In the Scotch Fir, these dwarf-shoots bear only two green acicular leaves in addition to scales, and arise in the axils of the scaly leaves of an ordinary shoot of the same year's growth. In forest-trees, these dwarf-shoots occur especially in advanced age, or when their growth is stunted; they are very conspicuous in the Apple and the Pear, and other similar trees, and are the only parts of the tree which produce flowers and fruit.

The stem of herbaceous plants is usually *erect*, but sometimes it is *prostrate*, as in Thyme; when, in this case, roots grow from the nodes, it is called a *creeping stem* (*soboles*, Fig. 14 *E*). *Stolons* are long, slender, lateral shoots which grow close upon or under the surface of the soil and take root again at some distance from the parent plant (*e.g.*, the Strawberry, Fig. 14 *D*). *Twining* or *climbing stems* are stems which produce leaves and flowers, and at the same time grow upwards round upright supports (Fig. 15 *B*), as the Hop, Bean, Convolvulus, and others (v. § 48). Other plants climb by means of *tendrils* (cirrhi), *i.e.*, slender, filiform, lateral shoots with only minute scale-like leaves which twist spirally round foreign bodies (Fig. 15 *A*), as in the Vine, Virginia creeper, Passion flower, etc.

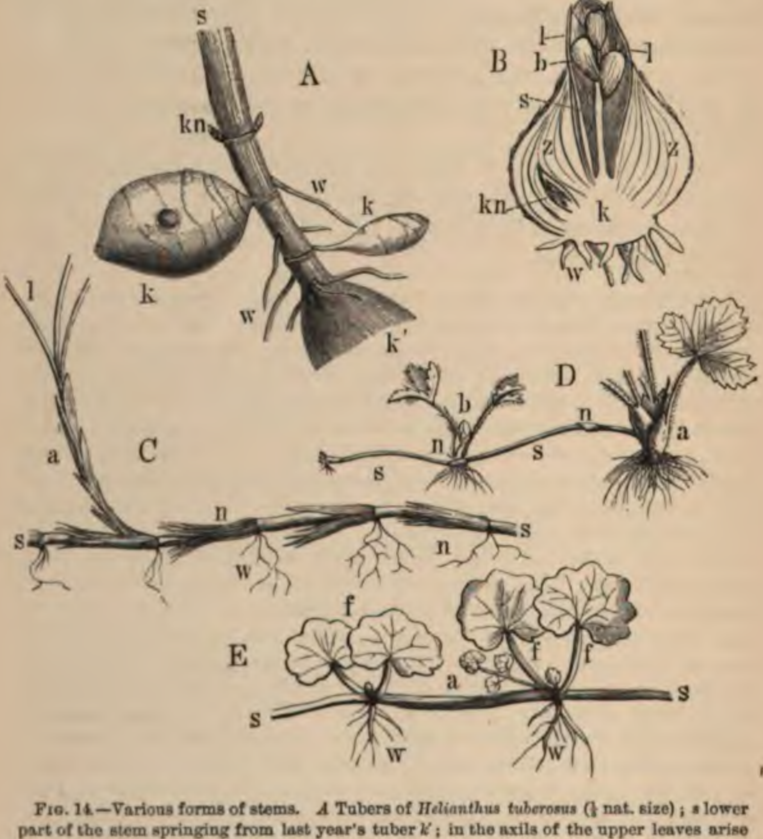

Fig. 14.—Various forms of stems. *A* Tubers of *Helianthus tuberosus* (⅓ nat. size); *s* lower part of the stem springing from last year's tuber *k'*; in the axils of the upper leaves arise the buds *kn*, and in those of the lower leaves the tubers *k* with very small scaly leaves and buds. *B*, Bulb of *Hyacinthus orientalis* (reduced); *k* the discoid stem, *z* the scales, *s* the stalk which subsequently elongates and bears the flowers above ground, with the buds *b*; *l* foliage leaves, *w* roots; *kn* an axillary bud which becomes next year's bulb. *C* Elongated rhizome of *Carex arenaria* (½); scaly leaves *n* of the rhizome *s*; *a* erect shoot with scaly and foliage-leaves l.—*D* Runner of the Strawberry, Fragaria (reduced), springing from the plant *a*, with scaly leaves *n*, from the axil of which a new runner *b* arises. *E* Creeping stem of the Ground Ivy, *Glechoma hederacea* (reduced); *f f* decussate leaves; the internodes are twisted; *a* axillary shoot; *w* root.

Many axial structures become *thorns*, being metamorphosed into hard, sharp-pointed bodies. Sometimes the apex of a shoot is modified in this way after it has produced leaves, *e.g.*, the Sloe (Fig. 16), or certain lateral shoots are developed as thorns from the first, as in Gleditschia, in which plant secondary thorns also are developed from the axils of scaly leaves.

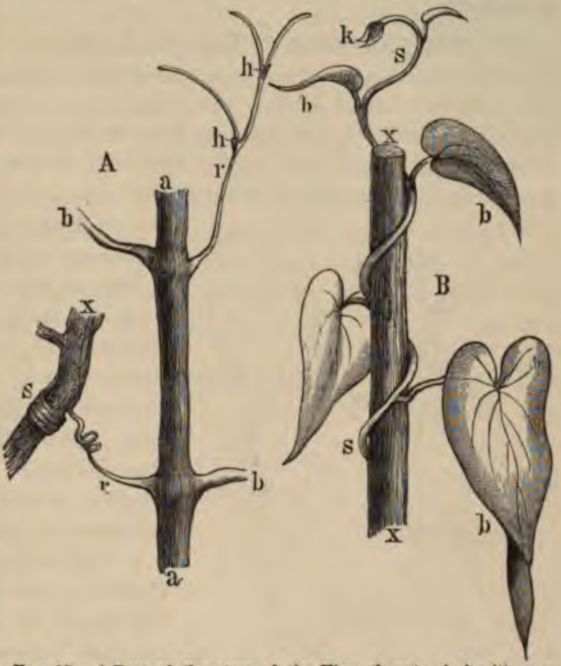

FIG. 15.—*A* Part of the stem of the Vine (⅓ nat. size) with two tendrils *rr*; the upper one bears small leaves *h* and branches; the lower one has become attached to a support *x* and has rolled up spirally; *bb* petioles; in this case the tendrils are branches which are peculiar in that they are opposite to the leaves. *B* Twining stem of Ipomœa, *s*, with leaves *b* and a bud *k*; *xx* is the support.

With regard to those subterranean stems which are commonly known as roots, and bear for the most part cataphyllary leaves, the most important varieties are — the *rhizome*, which differs but little from the ordinary typical stem; it grows horizontally under the earth's surface, and developes new aërial, herbaceous stalks and sometimes green leaves every year (Fig. 14 *C*): the *tuber*, which grows greatly in thickness and bears only minute scaly leaves; *e.g.*, the tubers of the Potato and of *Helianthus tuberosus* (Jerusalem Artichoke) (Fig. 14 *A k*): the *bulb* (Fig. 14 *B*), which consists of a flat discoid axis (*k*) bearing numerous crowded and overlapping leaves (*z*) *e.g.*, the Onion and Tulip, and the *corm* (Crocus) in which the axis is larger and the scales less numerous and more delicate.

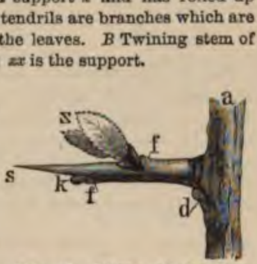

FIG. 16.—Thorn of the Sloe, *Prunus spinosa*, *a* branch, d leaf-scar, from the axil of which the thorny branch *s* springs; on the thorn are *ff* leaf-scars; in the axil of the upper one is the branch *x*, in that of the lower, the bud *k*.

The form of stem which differs most widely from the ordinary type is the *phylloclade*, which resembles a leaf in its appearance, and bears only very small true leaves, *e.g.*, the branches of Ruscus and Phyllanthus. In the

Cactus family there is the greatest diversity in the form of the stem; it may be leaf-like, spherical, cylindrical, columnar, etc.—but in all cases the leaves are rudimentary.

§ 6. **Development of Branch-Systems.** Just as it is possible to ascertain the laws governing the relative positions of all members growing in acropetal succession from a study of the leaves (which are always developed in that order), so the study of the branching of stems will lead to the general laws which regulate branching. By *branching* is meant the production of similar members:—thus it is an instance of branching when a root produces a lateral root. Any member with its branches composes a *branch-system*, and every branching member is, with reference to its branches, the *axis* of a system. The following types of branch-systems may be distinguished, according to the arrangement of the members:

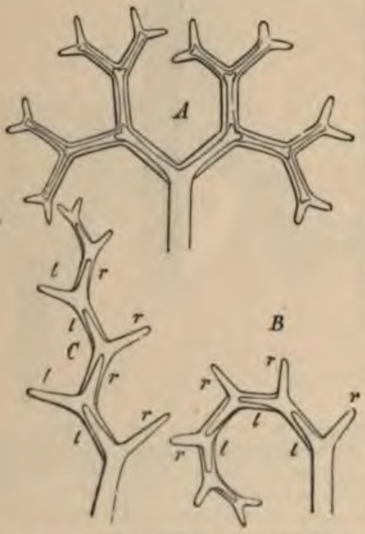

FIG. 17.—Diagram of the various modes of development of a Dichotomy. *A* One developed by bifurcation. *B* Helicoid dichotomy; here the left-hand branch is always more vigorous than the right (*r*). *C* Scorpioid dichotomy; the right and left branches are alternately more vigorous in their growth.

1. The branching is termed a *Dichotomy* or *Polyotomy*, when the direct apical growth of a member ceases, two or more growing-points which are equally vigorous, at any rate at their first development, being formed at the apex. The member which bears the branches is called the base or *podium*, and each of these branches may become the base of a new dichotomy or polyotomy. They may either continue to grow with equal vigour, and then, in the case of a dichotomy, the branching remains distinctly bifurcate (Fig. 17 *A*), or the system may become *sympodial*, if at each bifurcation one branch becomes more strongly developed than the other: in such a case the bases of the successive bifurcations appear to constitute an axis, which is called the *pseud-axis* or *sympodium*, on which the weaker branches appear as lateral branches (Fig. 17 *B*.*C*). The sympodium may consist of bifurcations belonging to the same side

of the successive dichotomies, either to the left or to the right (Fig. 17 *B*), when it is said to be a *helicoid* (*bostrychoid*) *dichotomy*, *e.g.*, the leaf of *Adiantum pedatum*, or it may consist alternately of the right and left bifurcations of successive dichotomies (Fig. 17 *C*), when it is said to be a *scorpioid* (*cicinal*) *dichotomy*.

Dichotomous branching is rather uncommon, and scarcely ever occurs in leafy shoots: it occurs in the roots of the Lycopodieæ and in the frondose Liverworts.

2. The branching is said to be *racemose* when the member continues to grow in its original direction, and produces lateral branches in acropetal succession behind its apex; it is therefore the common base of all the lateral shoots, and hence the system is termed *monopodial*. It is evident that this mode of branching must occur in all stems the lateral branches of which are dependent, as to their position, upon the arrangement of the leaves, and are therefore developed in acropetal succession. Each branch may subsequently branch again in the same manner. The primary axis continues to grow more vigorously than the lateral axes, and each lateral axis stands in the same relation to the lateral axes.

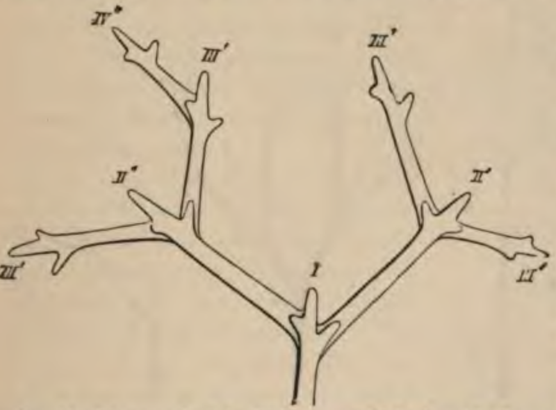

FIG. 18.—Diagram of a False Dichotomy or Dichasium; the Roman numerals indicate the order of development of the shoots of the system. Those numbered II' and II'' are equally vigorous, and much more so than the primary axis I. (From Sachs.)

3. The branching is said to be *cymose*, when at an early stage the growth of each lateral axis begins to be more vigorous than that of the primary axis above the point of origin of the lateral axis, and when the lateral axis becomes more copiously branched than the primary axis. Hence two forms may arise:

(*a*) *there may be no pseud-axis;* this is the case when two or more lateral axes are developed in different directions and grow with nearly equal vigour (Fig. 18) and more vigorously than the primary axis, which soon ceases to grow; such a system has a certain resemblance to a dichotomy or polyotomy, and is called a *false dichotomy* (Dichasium) or a *false polyotomy* (Polychasium): or (β) *a pseud-axis is formed;* this takes place when only one lateral axis developes vigorously in each case, as in Fig. 19 *A*, where the lateral axis 2 has grown more vigorously than the mother-axis 1, and so on. (In the diagram the dark lines indicate the more vigorous growth.) The pseud-axis which is thus formed is at first crooked, but in most cases it subsequently becomes straight (Fig. 19 *A* becomes *B*). If the stronger growth always occurs in the lateral shoots of the same

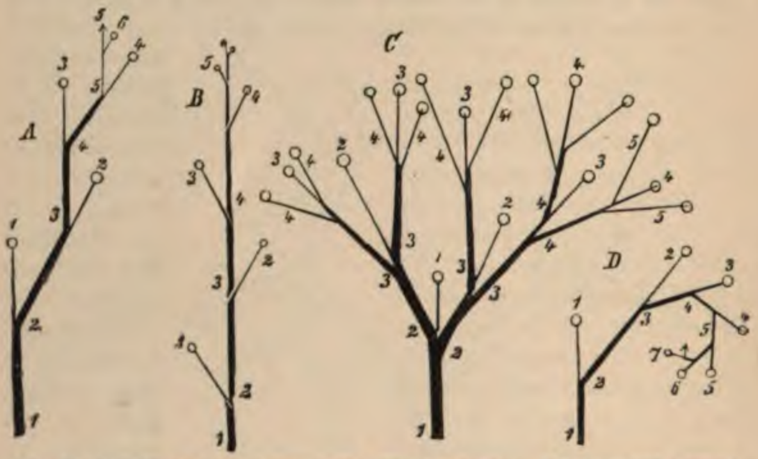

FIG. 19.—Cymose branchings represented diagrammatically. *A B* Scorpioid (cicinal) cyme. *C* Dichasial cyme. *D* Helicoid (bostrychoid) cyme The numerals indicate the order of succession of the lateral shoots which spring from each other, (Figs. A, B and D are ground-plans; Fig. C is a projection into the plane of the paper).

side, the system is called a *helicoid cyme* (Fig. 19 D); if alternately in those of both sides, it is called a *scorpioid cyme* (Fig. 19 *A B*). Such a branch-system is said to be *sympodial*.

As examples of these various modes of branching, the inflorescences, which will be treated of subsequently (Part IV.), may be especially mentioned; the following are selected from the vegetative organs:

Racemose branching is very evident in Conifers; the trunk is always more strongly developed than its lateral branches, and these than their lateral branches.

False Dichotomy is exhibited in the stem of Viscum, the apex of which either terminates in a flower or else dies; only the axillary buds of the two leaves develope into new annual shoots. As regards the arrangement of the annual shoots, the same occurs in Syringa, in which the axillary buds of the uppermost pair of leaves form the continuations of the stem, whilst the terminal bud dies; also in *Rhamnus catharticus*, in which the main axis is metamorphosed into a thorn. In this case the branching of each annual shoot is racemose, but the successive annual shoots form a cyme.

The succession of the annual shoots of many trees, as the Birch, Elm, Beech, and Hazel, affords examples of the *sympodial cyme;* in these, each annual shoot either terminates in a flower, or it dies, and the uppermost lateral bud forms its continuation. Here also the branching of each annual shoot, apart from its apex, is racemose.

§ 7. The term **Root** in its botanical sense is not applicable, as in ordinary parlance, to any subterranean part of a plant, but only to those members of a plant which are developed endogenously, which produce no leaves, and which have their growing-point protected by a peculiar structure, the *root-cap* (Fig. 20 *h*). The outermost cells of the root-cap are thrown off while new ones are continually being formed at the growing-point.

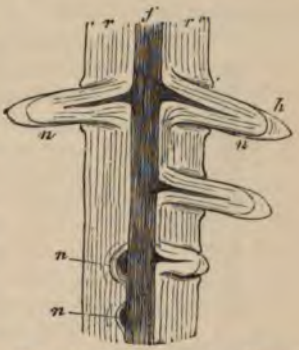

FIG. 20.—The side roots *n*, thrown out from the pericambium of the tap-root of *Vicia Faba*. (Longitudinal sec. mag. 5 times.) *f* Fibrovascular bundles. *r* Cortex of the main root. *h* Root-cap of the lateral roots.

Roots only occur in such plants as possess fibro-vascular bundles, and they themselves invariably contain such bundles; only a few vascular plants are entirely destitute of roots (Salvinia, *Lemna arrhiza*, etc.). The term *primary root* (tap-root) is applied to the root of a young plant which lies in the same straight line as its primary stem; in the Vascular Cryptogams and in the Monocotyledons it remains small, and it is only in the Dicotyledons (to which group the Bean, the Tobacco, the Hemp, and the Oak belong) and in the Gymnosperms, that it attains a considerable size in proportion to the rest of the plant. All the other roots—the *secondary* and the *adventitious*—originate laterally upon the primary root, or from the stem, or even from leaves. They invariably originate from an internal layer of tissue, and then break through the external tissues. On anatomical grounds (§ 25), the lateral roots are arranged in longitudinal rows on the main-root; at a later period, however, numerous adventitious roots are successively developed here and there between the original lateral roots.

The primitive form of roots is that of an elongated cylinder; only those roots which undergo a gradual growth in thickness and at the same time become succulent acquire a spindle shape, *e.g.*, Beetroot, or exhibit tuberous swellings, *e.g.*, the Dahlia. The *aërial roots* of many tropical plants, such as Tree-Ferns, Orchids, and Aroids, which serve to attach them to tall trees and other supports, are physiologically different from true roots. So, too, are the *climbing roots* of the Ivy, which grow close together from certain parts of the stem and remain quite short, serving as a means of secure attachment to walls and tree-trunks; also the *sucker-roots* of many parasitic plants, *e.g.*, Dodder (Cuscuta), which penetrate the tissues of the plant which nourishes them.

§ 8. **Hairs** or **Trichomes** are organs which are developed from the epidermis of a member. This category includes not only hairs in the strict sense of the word, such as will be described hereafter in § 29, but also many reproductive organs, such, for instance, as the sporangia of Ferns.

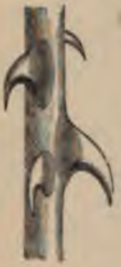

FIG. 21.—Prickles on the stem of the Bramble, *Rubus fruticosus* (nat. size).

Prickles, such as those of the Bramble or of the Rose, are usually included among trichomes (Fig. 21). They differ from true hairs in that they are formed not from the epidermis only, but from the subjacent tissue also, but they agree with them in that they are not arranged in any regular order, and are not the result of the modification of certain members (caulomes or phyllomes), as is the case with thorns and spines. Like the hairs they are merely appendages, the occurrence and arrangement of which does not materially affect the general structure of the plant. In order to indicate the fact that they are not developed in the same way as true trichomes, prickles and allied structures (warts, tubercles, etc.) may be designated as *Emergences*.

The ordinary hairs may be simple, or compound, they may be stellate, they may be hardened and elongated (setæ), or they may be glandular. According to the nature and number of the hairs upon it, a surface is said to be *pubescent* (the flower-stalks of the Primrose), *pilose* (leaves of the Sunflower), *hirsute* (*Myosotis sylvatica*), *setose* (Borrage, Echium), *villous* (*Anemone Pulsatilla*), *tomentose* (leaves of *Petasites niveus* and *spurius*), *silky* (leaves of *Salix alba*), *woolly* (*Stachys germanica*). If there are no hairs upon it, it is said to be *glabrous*.

§ 9. The body of the lower plants (Algæ, Fungi, and many Liverworts) exhibits no differentiation of stem, leaf, and root. It possesses organs which serve, like the roots of the higher plants, to fix the plant to the soil and to absorb nutriment, and frequently it exhibits branchings which resemble leaves; but these structures do not properly belong to the two categories as defined in § 1. Such a body is termed a *Thallus*. A thallus may, and very frequently does, bear true trichomes, such, for instance, as root-hairs.

PART II.

THE ANATOMY OF PLANTS.

§ 10. The members of the plant which have been described in Part I. agree, as to their external structure, in this, that they all consist of cells or of structures formed by the modification of cells. The cellular structure of the parts of plants may be easily observed: a section seen with even a low magnifying power shows cavities separated by walls. Sometimes it is possible by mere pressure to separate the cells forming a tissue, as in the case of the ripe Snowberry (fruit of *Symphoricarpus racemosus*), when they appear as closed vesicles filled with fluid. Certain cells always occur isolated; thus the pollen consists of isolated cells. The form and development of cells, the mode of their combination to form tissues, and the resulting texture of the tissue, may vary greatly. Since the variety of the tissues depends upon the development of the cells composing them, it will be advantageous to study cells, as such, first, and then the tissues.

CHAPTER I.

THE CELL.

§ 11. **The Structure and Form of the Cell.** In a well-developed living cell the following three principal constituents may be distinguished:

(1). A firm elastic membrane, closed on all sides, the *cell-wall* (Fig. 22 *C h*), which consists of a substance peculiar to itself, called *cellulose.*

(2). A layer of soft substance, the *protoplasm*, lying in contact with the inner surface of the membrane, and, like it, closed on all sides; this always consists of albuminous substances (Fig. 22 *C p*). In all the higher plants at least, a *nucleus* (Fig. 22 *C k*) occurs imbedded in it.

(3). A watery fluid, *the cell-sap*, which fills the whole space, called the *vacuole*, enclosed by the protoplasm (Fig. 22 *C s*).

The same cells in which these three parts may be distinguished, present, in their young state, when they are very much smaller (Fig. 22 *A*), quite a different appearance. At this period the protoplasm fills the whole cell; the cell-sap makes its appearance in the course of development, at first (Fig. 22 *B*) in the form of small drops. These, while the whole cell increases in size, gradually increase also and coalesce; while at the same time the bands of protoplasm which separate them are absorbed into the peripheral layer.

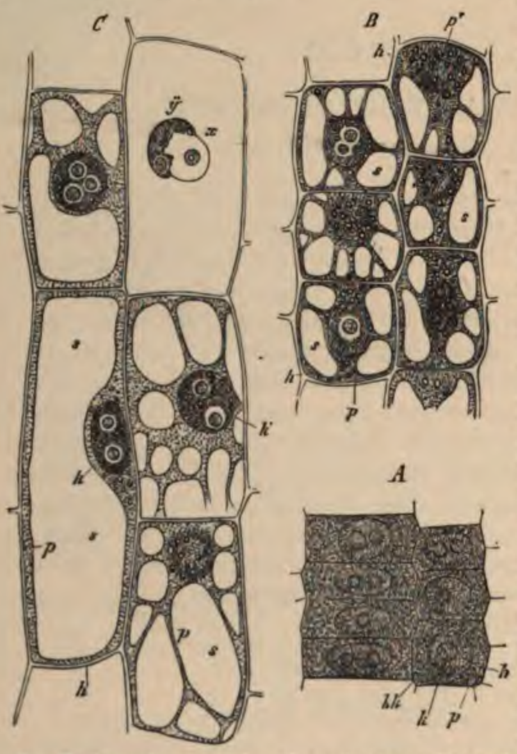

FIG. 22.—Parenchyma-cells from the cortical layer of the root of *Fritillaria imperialis*; longitudinal sections (× 550). *A* Very young cells lying close to the apex of the root, still without cell-sap. *B* Cells of the same description about 2 mm. above the apex of the root; the cell-sap *s* forms separate drops in the protoplasm *p*. *C* Cells of the same description about 7-8 mm. above the apex of the root; the two cells to the right below are seen in a front view; the large cell to the left below is in section; the cell to the right above is opened by the section; the nucleus shows, under the influence of the penetrating water, a peculiar appearance of swelling (*x y*). (Copied from Sachs.)

In this way these cells attain the condition in which they remain until the death of the organ of which they form part. They may be taken as examples of the cells which compose the succulent parts of plants, such as the cortex of stems and of roots, and fruits. Other cells, as for instance those of wood and cork, pass beyond this stage and become still further modified; the cell-sap and protoplasm disappear, so that at last only air or water is contained within their walls. But whilst cells of the former class, furnished with protoplasm, are capable of carrying on osmotic and chemical processes, and, under certain conditions, of giving rise to new cells,—that is to say in short, of living,—mature wood-cells, devoid of protoplasm, are no longer capable of performing these functions; they are of use only in virtue of the firmness and other physical properties of their walls. Hence the protoplasm is to be regarded as the living body of the cell. Indeed, there are cells which, when first formed, consist only of naked protoplasm, and they occur precisely in connection with the most important vital function of the organism—that of reproduction. Such cells are termed *primordial cells* (Fig. 37 *B*). They subsequently become surrounded by a membrane which is secreted by the protoplasm. From this it appears that the cell-wall, as well as the cell-sap, is a product of the vital activity of the protoplasm. It has been attempted to express the essential characters of the cell by describing it as *a mass of living protoplasm which usually surrounds itself with a firm membrane, and takes up fluid into itself.*

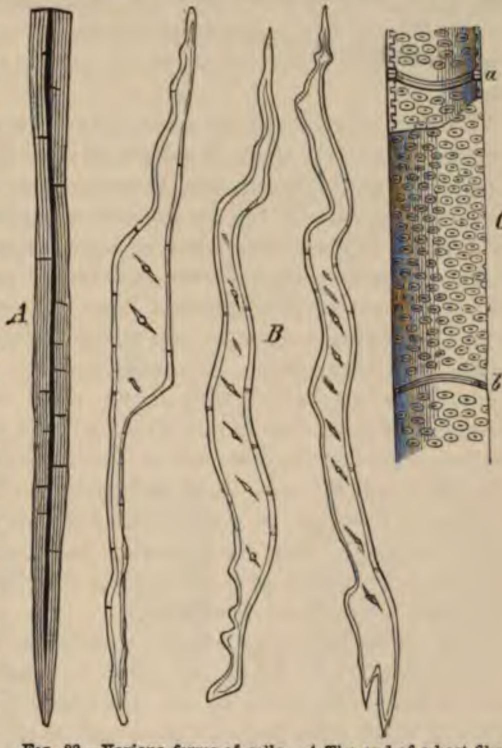

FIG. 23.—Various forms of cells. *A* The end of a bast-fibre, with strongly thickened pitted walls (longitudinal section × 300). *B* Wood-cells from the root of the Cucumber (× 300), surface-view and section. *C* Part of vessel with bordered pits from the stem of *Helianthus tuberosus* (× 300) cut open at the top. At *a* and *b* the remains of the absorbed septa are visible.

Various as the internal arrangements of the cell may be, its size and form may vary quite as widely. While some cells are so small that little more than their outline can be discerned with the help of the strongest magnifying power (about 0·001 of a millimetre in diameter), others attain a considerable size (from 0·1 to 0·5 millimetre), so as to be distinguishable even by the naked eye (for example, in the pith of the Dahlia, Impatiens, and Elder (Sambucus)). Many grow to a length of several centimetres, as the hairs upon the seed of Gossypium (cotton); others finally, as in some Algæ, where the whole individual consists of a single cell, attain still larger dimensions.

The *Form* of such cells as constitute an entire individual is often nearly spherical, or ovoid, or cylindrical; but they may also exhibit a highly complex conformation, in consequence of the assumption of quite different forms by the various outgrowths of one and the same cell. The various organs of highly organised plants consist of very different cells, and even in the same organ cells lie side by side which are of very different form, and which are filled with somewhat different contents, for diverse functions have to be performed by a single organ. The cells in such a case are sometimes spherical or polyhedral, with nearly equal or slightly differing diameters (Fig. 22 *C*, as in pith, in juicy fruits, and in fleshy tubers); sometimes greatly elongated and at the same time excessively narrow (Fig. 23 *A* and *B*), as in wood, in bast-fibres (Flax), in many hairs (Cotton). Longitudinal rows of cells frequently combine to form a special organ by the absorption of the transverse septa which separate their cavities (Fig. 23 *C*): it is thus that the *vessels*, as they are called, are formed. (See § 22.)

§ 12. **The Cell-wall** consists of cellulose, water, and inorganic constituents. It originates and grows in consequence of the secretion of these substances by the protoplasm. The growth of the cell-wall takes place both in extent and in thickness; it is effected by the intercalation of additional particles of solid matter between those already existing in the membrane.*

By its *superficial growth* the surface of the membrane and consequently the whole volume of the cell, is increased; so much so that the volume of the cell not unfrequently becomes a hundredfold greater. Thus, for instance, in a leaf enclosed in a leaf-bud, the cells, of which it will consist when mature, all exist already, and it is by their simultaneous increase in volume that the leaf attains its ultimate size. In the rare cases in which the superficial growth is equally great at all points, the cell preserves its original form, but usually the cell-wall grows more vigorously in certain parts than in others; thus, for instance, a primarily spherical cell may become cubical, tabular, cylindrical, tubular, fusiform, and so forth.

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* This mode of growth by intercalation of new solid particles between the existing particles is known as *intussusception*, and is essentially different from *apposition*,—that is to say, the deposition of new particles upon the surface of the growing body, as in crystals. This phenomenon is closely connected with the idea that in the cell-wall, as in starch granules and other organised bodies, the solid particles must be conceived of as being surrounded on all sides by water.

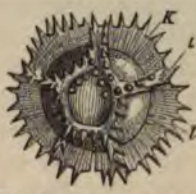


FIG. 24.—Ripe pollen-grain of *Cichorium Intybus*; the almost spherical surface of the cell-wall is furnished with ridge-like projections prolonged into spines, and forming a network. (After Sachs.)

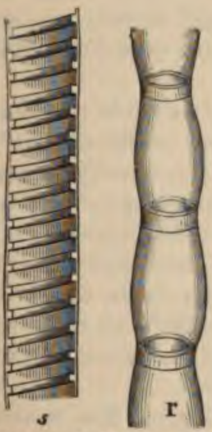


FIG. 25.—*r* Annular, *s* spiral thickening of the walls of vessels; *r* seen from outside, *s* in longitudinal section highly magnified (diagrammatic).

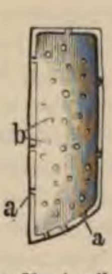


FIG. 26.—A cell with pitted walls from the wood of the Elder (Sambucus). A longitudinal section showing the pits in the lateral walls as channels, *a*; and in the farther wall as roundish spots, *b*. × 240.

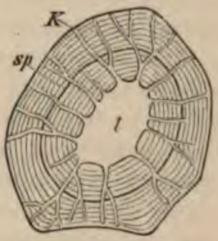


FIG. 27.—Transverse section of a bast cell from the root of *Dahlia variabilis* (× 800); *l* the cell-cavity; *K* pit-channels which penetrate the stratification; *sp* a crack by which an inner system of layers has become separated. (Copied from Sachs.)

The *growth in thickness* of the cell-wall is also rarely uniform; the cell-wall commonly becomes more thickened at some points than at others, and thus acquires inequalities of surface. In the case of isolated cells or of free cell-walls, the prominences existing in this way on the external surface appear as warts, tubercles, knots, etc. (Fig. 24). Cells that are united to form tissues have their inequalities on the internal surface of the cell-wall; the prominences sometimes have a definite form and project into the interior of the cell; such are the *annular* (Fig. 25 *r*) and *spiral* thickenings (Fig. 25 *s*) of the walls of certain vessels; in the so-called *reticulated* cell-walls, the thickening is in bands which are united into a network, so that circular or oval thin spaces are left. In other cases, solitary and relatively small thin spaces are left in the wall in the course of the growth in thickness, which appear, when seen on the external surface, as bright spots, commonly called *pits*, and are seen in section to be canals of greater or less length, according to the relative thickness of the walls (Figs. 26 and 27). Very frequently the pit, when seen from the surface, presents the appearance of two concentric circles (Fig. 23 *C*); for this reason, that the opening of the canal into the interior of the cell is narrow, whereas the external opening is broad. Such *bordered pits* occur in the wood-cells of Conifers (Fig. 42); in the walls of many vessels (Fig. 23 *C*); and elsewhere (Fig. 41). The *scalariform* thickening of the walls of many vessels arises from the regular and close arrangement of bordered pits which are much elongated transversely.

The cell-wall shows indications, in many cases very plainly, of an intimate structure which depends upon the regular alternation of more and less watery layers; this displays itself in transverse and in longitudinal section as concentric *stratification* (Fig. 27), and on the surface as *striation*.

Thin cell-walls generally consist, as regards organic substance, entirely of cellulose, which assumes a blue tint on the addition of iodine and sulphuric acid. In thickened walls it frequently happens that certain parts, composed of successive layers, consist of modified cellulose. The principal modifications are the following:—

(1). The cellulose may be converted into cork (cuticularized). The cuticularized cell-wall is extensible, highly elastic, almost impermeable to water; it turns yellow when treated with iodine and sulphuric acid (examples, the cells of the epidermis and of cork, pollen-grains, spores).

(2). The cellulose may be converted into lignin. The ligneous cell-wall is hard, inelastic, it is easily penetrated by water, but it does not absorb much; it turns yellow when treated with iodine and sulphuric acid (examples, wood-cells).

(3). The cellulose may be converted into mucilage. The mucilaginous cell-wall is, in its dry state, hard or horny; it can absorb a large quantity of water, and at the same time it increases greatly in volume, becoming gelatinous; it usually turns blue with iodine and sulphuric acid (examples, linseed and quince mucilage).

These modifications may occur either singly or together in the different layers of one cell-wall.

Mineral matters are also frequently deposited during growth in considerable quantity in the cell-wall, particularly salts of lime and silica; they are usually intercalated between the solid organic particles of the cell-wall, so that they cannot be directly detected, but remain after burning as a skeleton which retains the form of the cell. Silica is present in the stems of Grasses and of Equisetaceæ. Calcium carbonate sometimes occurs in a crystallized form (as in the epidermis of the Urticeæ), and calcium oxalate also in well-defined crystals (§ 18, Fig. 34).

§ 13. **The Protoplasm** consists principally of albuminous substances (proteids), water, and a small proportion of ash constituents. As it is the seat of all the vital phenomena and nutritive processes of the cell, it must obviously contain within itself at different times all the other chemical constituents of the organism. Sometimes it appears homogeneous and transparent, but it is generally more or less granular in consequence of the presence of drops of oil, of starch grains, etc. It is of a tenacious consistence, sometimes firm, sometimes almost fluid, but it is never a true fluid. When the protoplasm encloses granules, an outer layer free from granules can be detected, which is frequently very thin; this is called the *ectoplasm*, the inner granular portion being known as the *endoplasm*. Frequently a part of the water which saturates it collects to form vacuoles; when these coalesce and the cell-sap fills the greater part of the cavity of the cells (Fig. 22 *C s*), the protoplasm forms merely a layer within the cell-wall, which has been termed the *primordial utricle*. Living protoplasm will neither absorb colouring matter dissolved in water, nor allow its passage, but dead protoplasm has no power to hinder its diffusion, and even takes it up in considerable quantity.

The nucleus, on account of its constitution and position, is essentially a part of the protoplasm; it is apparently wanting in certain groups of lower plants (in some Fungi and Algæ). It contains one or more much smaller bodies called *nucleoli* (Fig. 22 *A k k*).

The movements of the protoplasm are among the most remarkable of phenomena. In many cells currents may be perceived which flow from the nucleus outwards, towards the peripheral protoplasmic layer (*Circulation*); or the whole peripheral layer of protoplasm is in rapid movement along the walls of the cell (*Rotation*). Naked primordial cells, as for instance, swarm-spores and antherozoids, swim about in the water in which they live, rotating at the same time on their own axes. The so-called plasmodia of Myxomycetes exhibit an amœboid movement; that is, the naked mass of protoplasm continually changes its outline, new protrusions are thrown out from the central mass, whilst others are withdrawn, and it thus moves slowly from place to place; at the same time a rapid motion of the granules within the mass is going on.

§ 14. **Crystalloids.** Sometimes a part of the protoplasmic substance assumes a crystalline form; bodies are formed which are bounded by plane surfaces and which have an angular outline, bearing a very close resemblance to certain crystals, for the most part cubical, octahedral, tetrahedral, or rhomboidal (Fig. 28); but they are essentially different from true crystals, inasmuch as they are capable of swelling-up, that is to say, of increasing considerably in volume when treated with various reagents. Such crystalloids occur, for instance, in the tuber of the Potato, in the aleurone-grains of oily seeds, in red marine Algæ, etc.

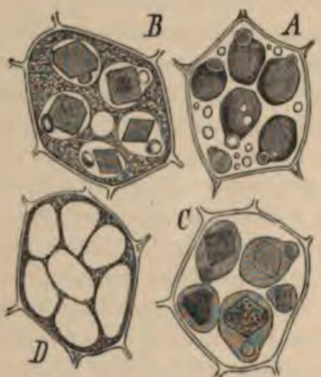


FIG. 28.—Cells from the endosperm of *Ricinus communis* (× 800). *A* fresh, in thick glycerine, *B* in dilute glycerine, *C* warmed in glycerine, *D* after treatment with alcohol and iodine: the aleurone-grains have been destroyed by sulphuric acid, the matrix remaining behind as a net-work. In the aleurone-grains the globoid may be recognised, and in *B C* the crystalloid.

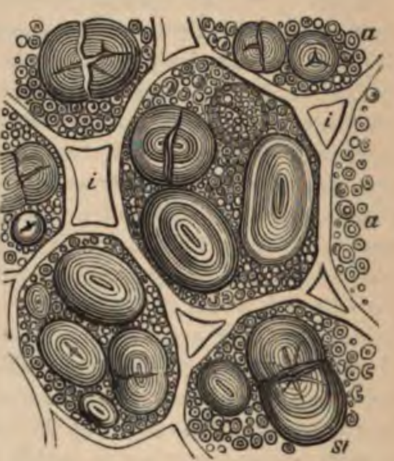


FIG. 29.—Cells of a very thin section through a cotyledon of the embryo in a ripe seed of *Pisum sativum*; the large concentrically stratified grains *St* are starch-grains (cut through); the small granules *a* are aleurone, consisting of proteids; *i* the intercellular spaces.

§ 15. **Aleurone-grains.** In oily seeds more especially, the protoplasm is aggregated into spherical granules of various sizes, which lie in a matrix of albuminous and fatty matter. These are the Proteid- or Aleurone-grains. These granules consist of albuminous substances, and almost always enclose other bodies (Fig. 28 *C*); these are the above-mentioned crystalloids, and peculiar small round bodies, the *globoids*, which consist of double phosphate of lime and magnesia. These bodies may occur separately or together in the aleurone-grains, according to the kind of plant. In seeds which are rich in starch, the spaces between the large starch-grains are filled with similar but much smaller granules (Fig. 29).

§ 16. **Chlorophyll-corpuscles.** The green colour of most parts of plants is produced by the presence of green granules, called *Chlorophyll-corpuscles*, in certain cells (Fig. 30). These are composed of a colourless ground-substance, throughout which a small quantity of a green colouring-matter called *Chlorophyll* is distributed. If this colouring-matter be extracted by a solvent, such as alcohol, the colourless corpuscle remains unaltered in size and form. The corpuscles are always imbedded in protoplasm, and their ground-substance is only a specialised portion of the protoplasm. The corpuscles do not always occur in the form of granules; in some of the lower Algæ the whole of the protoplasm, with the exception of the ectoplasm, is coloured green; in others, the coloured part of the protoplasm assumes a stellate form (Fig. 76 *A*), or it exists in plates (Fig. 76 *B C*) or spiral bands (Fig. 40 *cl*). These green-coloured portions of the protoplasm are all included under the general term, chlorophyll-corpuscles. Under the influence of sunlight starch-grains are formed in the interior of these chlorophyll-corpuscles, which often grow so large that the substance of the chlorophyll-corpuscle is only discernible as an extremely delicate layer covering the contents (Fig. 31).

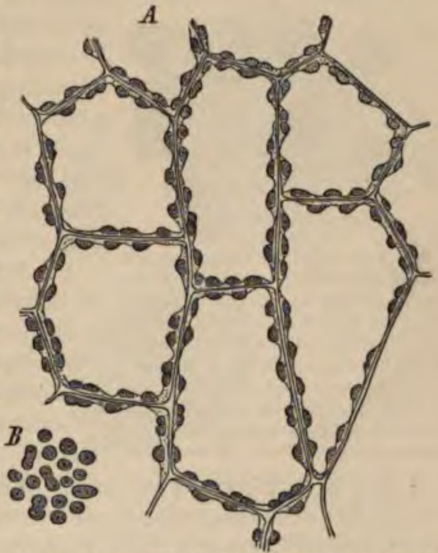


FIG. 30.—Chlorophyll-corpuscles in the protoplasm of the cells of the prothallium of a Fern. *A* Optical section of the cells; *B* part of a cell seen from the surface. Some of the corpuscles have begun to divide.

The ultimate fate of the chlorophyll-corpuscles is to be absorbed, as happens, for instance, in the cells of leaves before they fall, and nothing then remains but small yellow granules.

The green colouring-matter, the chlorophyll, is mixed, in many families of Algæ, with other colouring-matters, and the coloured protoplasm appears bluish-green, olive-green, dull yellow, or red. Occasionally the chlorophyll itself undergoes modification and becomes red or yellow, and the form of the corpuscle changes at the same time, as in the ripening of many fruits, which are at first green and then become yellow or red; *e.g.*, the Tomato (*Lycopersicum esculentum*).

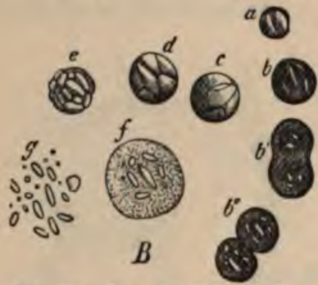


FIG. 31. — Separate Chlorophyll-corpuscles with starchy contents from the leaf of *Funaria hygrometrica* (550). *a* A young corpuscle, *b* an older one, *b'* and *b''* have begun to divide, *c d e* old corpuscles in which the starchy contents fill almost the whole space, *f* and *g* after maceration in water by which the substance of the corpuscle has been destroyed and only the starchy contents remain. (After Sachs.)

Closely related to the chlorophyll-corpuscles are those protoplasmic bodies which are tinged with a yellow colouring-matter, and cause the yellow colour of many flowers; *e.g.*, the Dandelion (*Taraxacum officinalis*).

In many cases the green colour of different parts of plants is disguised by the presence of other colouring-matters which are in solution in the cell-sap, as in the leaves of Amaranthus and of the Virginian Creeper at the end of the summer.

§ 17. **Starch-grains** are small hard granules, usually round, oval, or lenticular, consisting of starch, water, and a small proportion of incombustible ash, which occur in certain cells of almost all plants. The tubers of the Potato, the seeds of cereal and of leguminous plants are especially rich in them. They can be extracted by maceration from the organs in which they occur, and then appear to the naked eye as a white powder, which is known as *Starch*. Starch belongs, like Cellulose, to the carbo-hydrates. It may be easily shown that each grain consists of two substances, of which the one, *Granulose*, can be extracted by saliva or by dilute acids, while the other, *Starch-cellulose*, remains as the skeleton of the grain. The former turns blue with iodine alone, the latter only after treatment with strong sulphuric acid. When boiled with water or when treated with potash, the grains swell enormously and form a paste. The substance of the starch-grains is always disposed in layers round a centre, the *hilum*, and this disposition in layers, as in the case of cell-walls, is the result of the regular alternation of dense layers with more watery layers. The hilum is the most watery portion of the whole grain. From their first appearance the starch-grains are firm, solid bodies. So long as they continue to grow, they are always connected with the protoplasm of the cell; it is only at a later stage that they lie free in the cavity of the cell. Their growth does not proceed by the deposition of new layers upon the exterior, but by the intercalation of new particles of solid matter between those which already exist. Besides the simple grains (Fig. 32 *A*), compound grains occur, which are formed by the development of new hila in an ordinary grain, each with its own system of layers (Fig. 32 *D*). If, in such a case, the external layers which enclose the whole mass are of considerable thickness, the grain is said to be semi-compound (Fig. 32 *B*). By pressure the compound grains may be split up into their component granules. The so-called spuriously-compound grains are very similar to these; they consist of several grains which have become adherent in consequence of mutual pressure; they occur frequently in chlorophyll-corpuscles (Fig. 31). Starch-grains are formed in plants to be subsequently consumed in the processes of growth and of nutrition; they are frequently stored for a long time in certain organs, as in seeds, roots, and tubers, and when they are required for consumption on germination or on a renewal of the growth of the plant, they are absorbed. The forms of the starch-grains are characteristic in different kinds of plants; thus those of the Potato (Fig. 32) are eccentrically oval, those of leguminous plants (Fig. 29) concentrically oval, those of Rye, Wheat, and Barley lenticular.

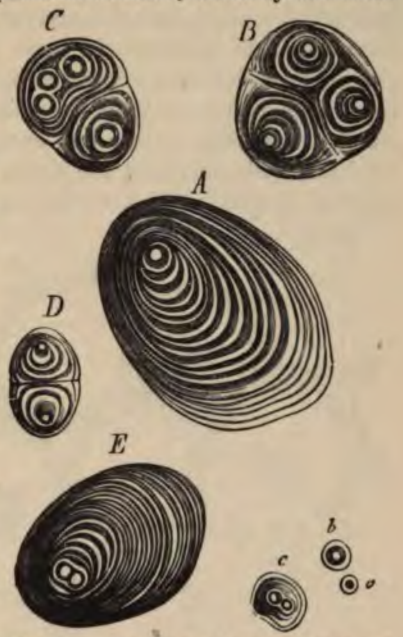
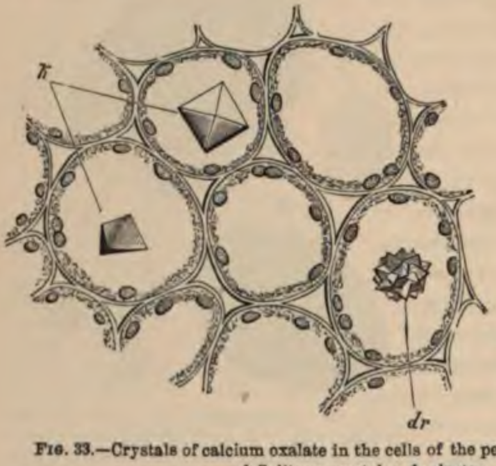


FIG. 32.—Starch-grains from the tuber of a Potato (× 800). *A* An older simple grain; *B* a partially compound grain; *C D* perfectly compound grains; *E* an older grain, the hilum of which has divided: *a* a very young grain, *b* an older grain, *c* a still older grain with divided hilum. (Copied from Sachs.)

§ 18. **Crystals** (see also p. 31) are frequently found in the cells of plants: they sometimes consist of calcium carbonate; for example, the crystals in the protoplasm of Myxomycetes and the crystalline deposit in the cell-walls of certain Urticeæ. In these plants there is generally a peculiar club-shaped ingrowth of the cell-wall of certain cells which projects into the interior of the cell, in which the calcium carbonate is deposited: these are called *Cystoliths*. All the other crystals hitherto recognised consist of calcium oxalate, which crystallises in two systems according to the proportion of water which it contains; to the one system, the quadratic, belong the octahedra (Fig. 33 *k*), to the other, the clinorhombic, belong the acicular crystals, which are called *Raphides*, and which occur, united into large bundles, particularly in Monocotyledons. Besides well-formed solitary crystals, aggregations of them also frequently occur. These crystals are formed in the protoplasm, from which they subsequently find their way into the cell-sap (Fig. 33), as well as in the cell-wall, particularly in the wood of Conifers (Fig. 34); and also in Lichens, on the free outer surface of the cell-wall.



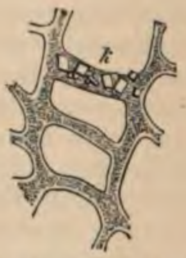


FIG. 34.—Crystals of calcium oxalate in the wall of the bast-cells of *Cephalotaxus Fortunei* (× 600, after Solms).

FIG. 33.—Crystals of calcium oxalate in the cells of the petiole of a Begonia (× 200). *k* Solitary crystals; *dr* cluster.

§ 19. **The cell-sap** saturates the cell-wall, the protoplasm, and the whole organic structure of the cell; it usually also collects in the interior of the protoplasm so as to form vacuoles or a single large sap-cavity. It is a watery solution of various substances: salts are never absent from it; in certain cells of many plants (as the Sugar-cane, the Maple, and the Beet-root) it contains large quantities of cane-sugar, which can be extracted from it by a refining process; in the cells of many kinds of fruits, as the grape and others, it contains grape-sugar. Besides these substances, tannin and inulin occur, as well as acids, such as malic acid in the apple and other fruits, citric acid in lemons, etc. It also contains the colouring-matters of most red and blue flowers (Erythrophyll and Anthocyanin), and of many fruits, as the cherry and elder berry, with many other substances.

§ 20. **The Development of Cells** always takes place in such wise that the whole or part of the protoplasm of a cell already existing, *the mother-cell*, undergoes re-arrangement. The following are the principal modes of cell-formation:

I. *Cell-division.* The protoplasm of the mother-cell separates into two or more parts, each of which constitutes a new cell. The division of the protoplasm is usually preceded by that of the nucleus.

Cases in which the protoplasm has been observed to divide *before* the nucleus occur in the development of the spores of Anthoceros and of the macrospores of Isoëtes.

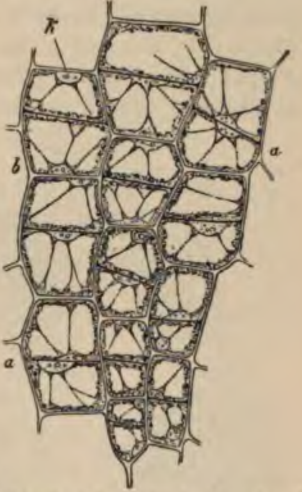


FIG. 35.—Cell-division in the cortex of the growing stem of *Vicia Faba* (× 300). At *a* the division has just taken place, the nucleus *k* still adheres to the new wall; at *b* it has retreated to the older wall.

In the simplest case of cell-division the nucleus divides into two, the protoplasm does the same, and a cell-wall is formed in the plane of division. In other cases the secondary nuclei and their investing protoplasm may again divide before any cell-wall is formed. Finally, the formation of a cell-wall may be postponed until the division of the nuclei and of the protoplasm has been repeated an indefinite number of times. The varieties of cell-division which thus arise may be arranged as follows:

1. In growing vegetative organs, a division of the cell takes place, such that the whole of its protoplasm, without any rounding-off or contraction, is divided into two parts: the new wall is formed between the two masses of protoplasm *only* along the plane of division (Fig. 35). The wall is sometimes formed simultaneously at all points of the plane of division, as in the development of stomata, and sometimes, as in certain Algæ, *e.g.*, Spirogyra, it grows as a ring from without inwards.

2. The formation of the cells which subserve reproduction (see § 55) is always accompanied by a rounding-off of the protoplasm, which takes place either before or during the formation of the new wall. In this case the wall is always formed over the whole surface of the young cells, though this often occurs somewhat late.

a. The whole protoplasmic contents of the mother-cell may become aggregated around four newly-formed nuclei; this process occurs principally in the formation of the pollen of phanerogamous plants (Fig. 36), and in the formation of the spores of Mosses and Vascular Cryptogams. The details of this process are not the same in all cases. In some (development of the pollen-grains of Monocotyledons and of the microspores of Isoëtes) the nucleus of the mother-cell divides into two, and this is followed by a corresponding division of the protoplasm, a cellulose wall being formed between the two cells. Each of these now divides in the same manner, in a plane at right angles to that of the first division, and thus the four special mother-cells are produced lying in one plane. In other cases (development of the pollen-grains of Dicotyledons, of the spores of Mosses, Ferns, and Equisetums) the nucleus of the mother-cell divides into two, and each of these secondary nuclei divides again into two, the divisions taking place in planes at right angles to each other and to that of the first division; as a consequence, the four

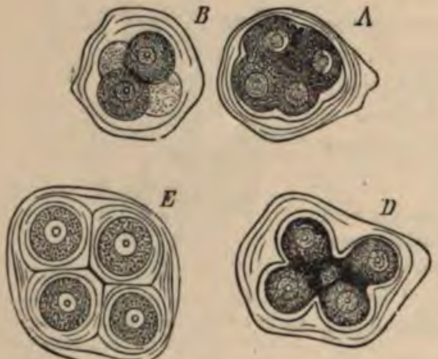


FIG. 36.—Division of the mother-cells of the pollen-grains of *Althæa rosea*. At *A* and *B* the division of the protoplasm into four has begun; in *D* the in-growth of the membrane is far advanced, and in *E* the walls are complete. (After Sachs.)

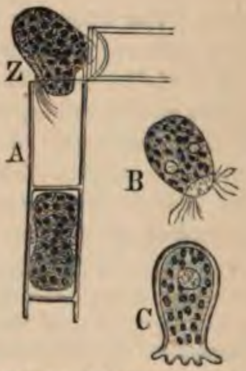


FIG. 37.—Rejuvenescence as exhibited in the formation of the swarm-spores of Œdogonium. *A* Portion of a filament; in the lower cell the protoplasm is beginning to contract, in the upper the young primordial cell is escaping (*Z*). *B* A swarm-spore. *C* The beginning of germination (× 350).

nuclei do not lie in one plane, but are arranged tetrahedrally. Cell-walls are now formed, so that four special mother-cells are produced. In the case of the pollen-grains of Dicotyledons, the wall of the primary mother-cell thickens and grows inwards at certain points (Fig. 36 *D*) so as to constrict the protoplasm somewhat, and the newly-formed walls become attached to these projections. In all cases each of the four special mother-cells surrounds itself with a proper wall which becomes the coat of the pollen-grain or of the spore.

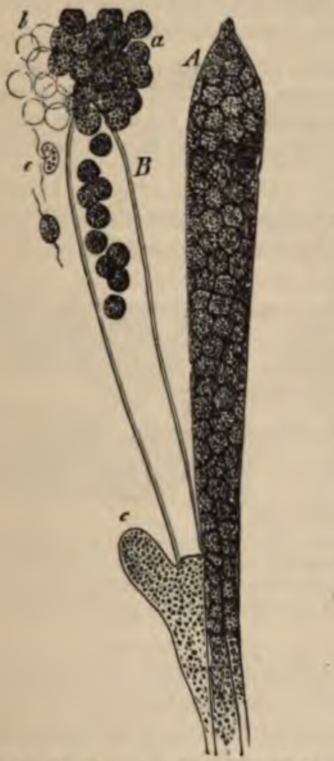


FIG. 38.—Zoosporangia of an Achlya (× 550). *A* Still closed. *B* Allowing the zoospores to escape, beneath it a lateral shoot *c*; *a* the zoospores just escaped; *b* the abandoned membranes of the zoospores which have already swarmed; *e* swarming zoospores. (Copied from Sachs.)

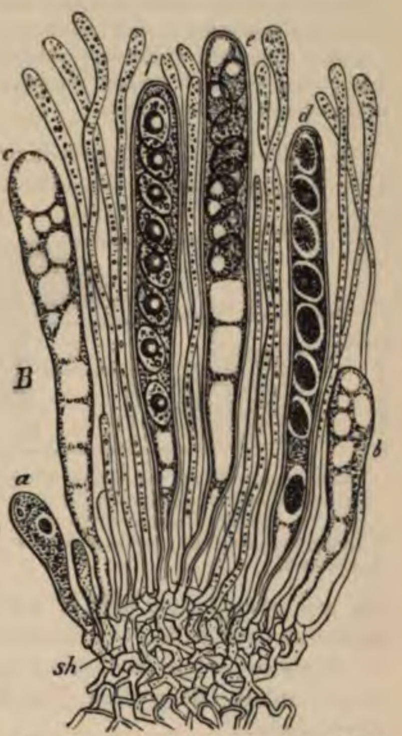


FIG. 39.—Cell-formation in the asci of *Peziza convexula*. *a f* Successive steps in the development of the asci and spores. (After Sachs, × 550.)

b. The number of the nuclei derived by repeated division from the nucleus of the mother-cell before any cell-wall is formed is indefinite. Each of them becomes surrounded by a portion of the protoplasm.

It is in this way that the zoospores of many Algæ and Fungi are formed (Fig. 38), and it is usually not until some time after their escape from the mother-cell that they become clothed with a cell-wall. The spores formed in the asci and sporangia of Fungi (Fig. 39 (are also developed in this way, but in this case the cells are always invested by a cell-wall before they are set free from the mother-cell. A further example of this is to be found in the development of the endosperm-cells in the embryo-sacs of phanerogamous plants.

This mode of cell-formation is known as *free cell-formation*, but the sense in which this expression is now used is very different from that in which it was originally employed. It was supposed that, in these cases, the secondary nuclei were formed *de novo*, but recent researches have shown that they are developed in the manner described above.

II. *Rejuvenescence.* The whole protoplasm of the mother-cell may undergo rejuvenescence, when it contracts and reconstitutes itself as the new protoplasmic body of a daughter-cell, which subsequently surrounds itself with a new membrane. It is in this manner that the single swarm-spores of many Algæ are formed, as in Vaucheria, Stigeoclonium, Œdogonium (Fig. 37), as well as the oospheres of Cryptogams.

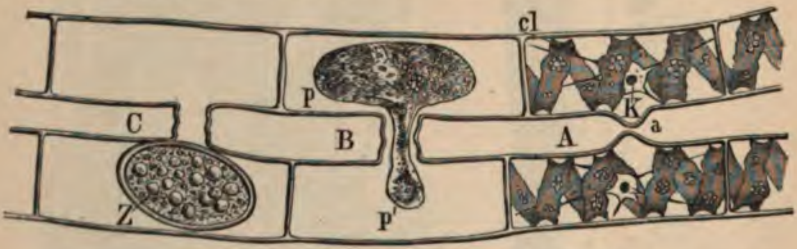


FIG. 40.—Conjugation of the cells of Spirogyra (× 400). *A* The cells of two filaments which are prepared for conjugation. At *a* the filaments have begun to swell towards each other. The spiral bands of chlorophyll are recognisable at *cl*, and the nucleus at *K*. At *B* the protoplasm of the cell p is fusing with that of the other p′. At *C* is a perfectly-formed Zygospore *Z*.

III. *Conjugation.* In conjugation the protoplasmic contents of two or more cells coalesce to form a new cell, which acquires a membrane. This process occurs in a typical manner in various groups of Algæ, *e.g.*, Spirogyra (Fig. 40), and of Fungi.

The formation of new cells does not therefore necessarily imply an increase in number; this is the case only when division into two, four or many cells occurs; in the process of rejuvenescence the number is unaltered, and in conjugation it is actually diminished.

CHAPTER II.

THE TISSUES.

§ 21. Those combinations of cells are designated **Tissues** which are governed by a common law of growth. According to their arrangement in space, the following combinations of cells may be distinguished:

A. *Filaments*, where the cells are connected only by their contiguous ends, and so form a filament, *e.g.*, many Algæ, as Spirogyra (Fig. 40), Œdogonium (Fig. 37), and many hairs (Fig. 62 *a d*).

B. *Surfaces*, when the cells form a single layer and are in contact in two directions of space (length and breadth), *e.g.*, many Algæ and the leaves of many Mosses.

C. *Masses*, when the cells are in contact on all sides.

The tissues commonly consist of cells which have originated from common mother-cells by their repeated division into two, and which have been connected from the first in consequence of the mode of formation of the septa (Fig. 35). In a few special cases tissues are formed otherwise (*spurious tissues*); either cells which have been hitherto isolated become adherent and then continue their growth in common, or filaments consisting of rows of cells become interwoven and exhibit a common growth, without however having become adherent in every case (Fig. 39 *sh*).

§ 22. **The Common Wall** of cells combined into a tissue is, in the first instance, usually extremely thin and delicate, and appears under the strongest magnifying power as a simple plate (Fig. 35). As it increases in thickness a *middle lamella* usually becomes visible (Fig. 41), which divides the wall into two parts, one of which apparently belongs to each of the contiguous cells. This middle lamella is nothing more than a specially differentiated part of the wall which belongs to both of the cells in common. Its chemical composition, which is different to that of the remainder of the wall, permits of its

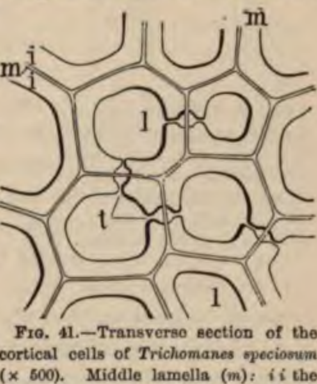


FIG. 41.—Transverse section of the cortical cells of *Trichomanes speciosum* (× 500). Middle lamella (*m*): *i i* the cell-wall adjoining the lamella; *l* cell cavity; *t* bordered-pits which meet in adjoining cells; the pits on each side are divided by the middle lamella.

solution (in nitric acid and chlorate of potash), so that the individual cells may be separated. When the common wall of similar cells is pitted, the pits on each side accurately meet (Fig. 41 *t*); if, however, certain cells of a tissue undergo a special modification, as in the vessels, the unequal thickening of the membrane is confined to one side only of the common wall; in the case of spiral thickening of the cell-wall this is self-evident.

The bordered-pits, which are characteristic of the wood-cells of Conifers, demand special description. The membrane which separates the cavities of the pits does not lie in the centre as a continuation of the cell-wall, but inclines to one side or the other, and lies over one of the canals (Fig. 42 *B s*): there is thus a lenticular cavity in the wall which opens freely into one of the two cells, but is shut off from the other: the membrane is so delicate that its presence may easily be overlooked. The formation of a bordered-pit is effected by the thickening of the cell-wall round a small area which remains thin (the persistent membrane), the middle lamella being prolonged so as to surround the cavity of the pit (Fig. 42 *B m*).

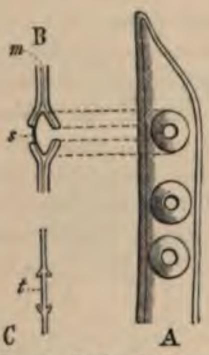


FIG. 42.—Bordered-pits on the woody fibres of the Pine: *A* seen from the surface; *B* in section; *s* the persistent membrane; *m* the middle lamella; *C* an earlier stage, in section; *t* the commencing pit (× 500, diagram).

In certain cases the septa between the cavities of adjacent cells become wholly or partly absorbed, as, for instance, occasionally the thin partition between bordered-pits; the transverse walls of such cells as combine to form the vessels are wholly absorbed, if they lie at a right angle to the long axis of the vessel (Fig. 23 *C a b*); if they lie obliquely, they are broken through in various ways. In a similar manner the transverse septa (and more rarely isolated areas on the longitudinal wall also) of the sieve-tubes (§ 25, Fig. 47 *B*) are perforated by closely-set and very fine open pits, and are then known as *sieve-plates*.

The thin part of the wall which separates the pit of a vessel from a contiguous living cell may frequently recommence its growth, and protrude into the cavity of the vessel. Cells which thus grow into neighbouring vessels are termed *tüllen*: they may subsequently undergo division so as to fill up the whole vessel. They occur commonly in wood.

Such cavities as have thus originated by the absorption of cell-walls and the consequent coalescence of two cells, and which continue to be surrounded by the walls of the original cells, are commonly called *cell-fusions*. They are usually tubular, and are formed by the absorption of the transverse septa throughout whole rows of cells. They are not unfrequently branched, and they may anastomose. The true vessels of plants, as well as the laticiferous vessels, are examples of cell-fusions.

§ 23. **Intercellular Spaces** are lacunæ between the cells of a tissue. They may be formed in two ways, either by a splitting of the common wall of adjacent cells, or by the disorganization of certain cells. They contain either air or certain peculiar substances.

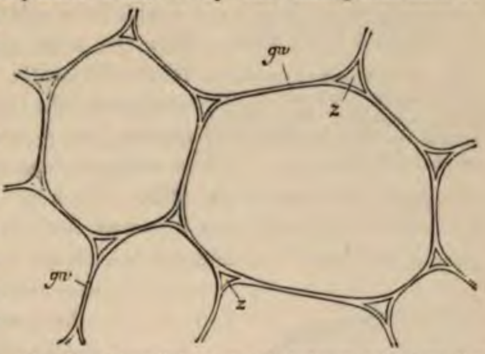


Fig. 43.—Intercellular spaces (*z*) between cells from the stem of *Zea Mais* (× 550); *gw* the common wall. (After Sachs.)

The intercellular spaces which contain air are usually formed in consequence of the splitting of the common wall of adjacent cells (Fig. 43 *z*). They occur almost exclusively between the thin-walled cells of succulent parenchyma, and usually at the angles of junction of a number of cells. Sometimes these spaces—then called *air-chambers*—attain a considerable size, so that whole masses of tissue are separated from each other, as in the petioles of the Water Lily and of other aquatic plants. The cells which border upon these cavities often throw out protuberances into them (also in Aspidium) which are known as "internal hairs."

The large cavities in the stems and leaves of Juncus and of other allied plants, are produced by the disorganization (*i.e.*, the drying-up and rupture) of considerable masses of cells: this is true also with reference to the cavities extending through whole internodes of many herbaceous stems (Grasses, Umbelliferæ, Equisetaceæ), and those occurring in leaves (Leek).

The intercellular spaces which contain certain peculiar substances will be treated of in § 28.

§ 24. **Forms and Systems of Tissue.** There are usually in plants numerous similar cells which differ from those that surround them, and which are combined so as to constitute a distinct *form of tissue*, characterized by those properties which the cells possess in common. According to the form and relative position of the cells, two forms of tissue may be distinguished: *parenchyma* (Figs. 22, 29, 33, 43), in which the cells are not much longer than they are broad, the surfaces along which they are in contact being relatively broad; *prosenchyma* (Fig. 44 and section Fig. 41), in which the cells are much longer than they are wide, and their ends overlap. When the walls of the cells are much thickened, the tissue is called *sclerenchyma* (see p. 58); this may be either parenchymatous or prosenchymatous, according to the form of the cells. When all the cells of a tissue have ceased to divide and have assumed their definite form, it is called *permanent* tissue. A tissue in which, on the contrary, the cells are still dividing, that is, that certain daughter-cells continue to divide and subdivide whilst the others are being converted into permanent tissue, is called a generating tissue or *meristem*. The enumeration here given only includes the most important forms of tissue; many other technical terms will be made use of in describing the tissues, as circumstances may require.

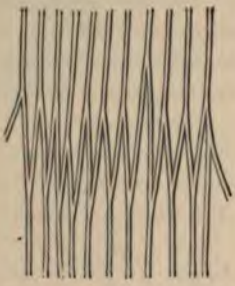


FIG. 44.—Prosenchymatous tissue, longitudinal section (diagram, magnified), the pointed ends of the elongated cells fit in between each other.

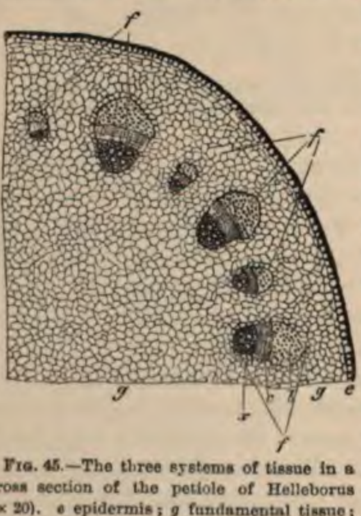


FIG. 45.—The three systems of tissue in a cross section of the petiole of Helleborus (× 20). *e* epidermis; *g* fundamental tissue; *f* fibro-vascular system; *x* xylem; *c* soft-bast; *b* bast-fibres.

When several different tissues occur in one plant, as in vascular plants in general, they are arranged into *systems of tissues* which then compose the whole plant; their arrangement bears a definite relation to the member of the plant in which they occur. Three such systems of tissues are usually met with: (1) the *epidermal*, which covers the exterior of the plant, and usually consists of a single layer of cells (Fig. 45 *e*); (2) the *fibro-vascular* (Fig. 45 *f*), which traverses the body of the plant in the form of bundles, and is characterized by the presence of sieve-tubes, vessels and of fibrous prosenchymatous cells; and (3) the *fundamental tissue*, which fills up the rest of the space (Fig. 45 *g*), and consists principally of parenchyma.

The same form of tissue may occur in various tissue-systems: thus both parenchyma and prosenchyma occur in all three tissue-systems, and there is no difficulty in recognising to which one they belong in each case. Certain tissues and peculiar cells—for instance, such as serve as receptacles for various substances, secretions, etc.—when they occur in the two internal tissue-systems, have so much in common that it may be expedient to consider them by themselves.

§ 25. **The Fibro-vascular System** extends throughout the body of the higher plants in the form of strands or bands of tissue which are called *fibro-vascular bundles*. When the cells which compose them are lignified, and are harder than those of the fundamental tissue, as is usually the case, they may be easily separated from it; for instance, if the leaf-stalk of the Plantain (*Plantago major*) be broken across, the bundles project as tolerably thick threads from the fundamental tissue, and by the decay of this tissue they may be wholly freed from it. They form the venation of leaves, and when the leaves decay they persist as a skeleton. In many water-plants, however, the tissue of the fibro-vascular bundles is softer than the surrounding tissues. In many cases the fibro-vascular bundles are so closely packed, and they become so strongly developed in consequence of the continued increase of their tissue, that very little of the fundamental tissue remains in the compact mass which they form. The wood of trees, including the bast, is an instance of such a fibro-vascular mass.

The arrangement and the course of the fibro-vascular bundles are intimately connected with the morphology of the plant, and with the differentiation of its members. In most leaves the fibro-vascular bundles lie in those projections of tissue which are known as veins. In the petiole and stem, and generally in all organs which grow especially in length, the fibro-vascular bundles run longitudinally: thus a transverse section of a stem or petiole (Fig. 45) exhibits transverse sections also of its fibro-vascular bundles. The bundles of the leaf and stem are so closely connected that even at the first development of the leaf at the apex of the stem, the upper

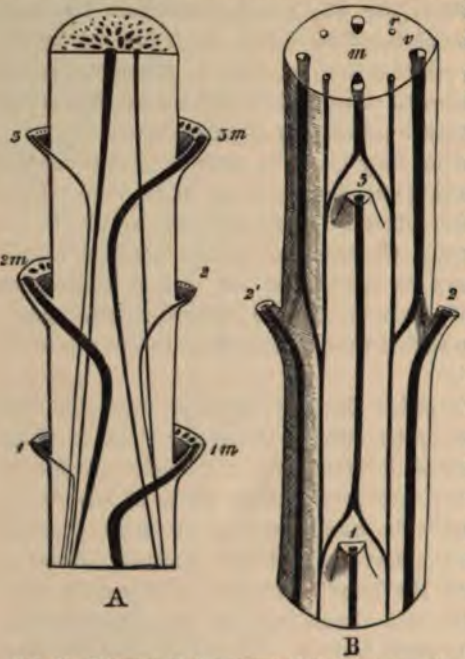


FIG. 46.—Diagram of the course of the fibro-vascular bundles in stems. *A* Longitudinal section through the axis of a Palm-stem, showing a transverse section of half of it. The leaves (cut off above the insertion) are hypothetically conceived of as distichous and amplexicaul, and so are seen on both sides of the stem, *m*1 *m*2 *m*3 being the median line of each. *B* Outside view and transverse section of Cerastium (hypothetically transparent to show the internal bundles). The decussate leaves are cut off. The bundle proceeding from each leaf divides into two above the leaf immediately below it, and the branches of all the bundles unite to form the four thin bundles which alternate in the section with the thicker ones. In the section, *m* is the pith, *r* the cortex, *v* the medullary ray. The xylem in the fibro-vascular bundles is indicated by shading.

end of each bundle bends outwards into a leaf, while the lower portion is continued downwards into the stem and coalesces with older bundles. Thus the fibro-vascular bundles traversing the stem may be regarded as being merely the lower portions of those which come from the leaves—as *leaf-traces*, and the whole bundle is said to be *common* (*i.e.*, to both leaf and stem). The course of these bundles in the stem is very various; it may in general be referred to one of three types, which are, however, connected by intermediate forms:

(1.) The bundles coming from the leaves unite and form a single axial bundle, which runs down into the stem (this type occurs but rarely, in certain water-plants and a few Ferns).

(2.) The bundles coming from each leaf are numerous: on entering the stem side by side, they tend towards the middle of the stem; then they bend outwards and thin out gradually as they descend, coalescing at a point much lower down (Fig. 46 *A*). In the transverse section of such a stem, the fibro-vascular bundles appear irregularly arranged; those nearest the centre are the thickest. This arrangement prevails among the Monocotyledons, particularly the Palms.

(3.) The bundles of each leaf, which are less numerous than in the foregoing type, bend downwards soon after they have entered the stem, and run down the stem parallel to each other at about an equal distance from the axis, branching and anastomosing particularly at the nodes (Fig. 46 *B*). The transverse section of such a stem exhibits the bundles arranged in a circle more or less nearly concentric with the circumference, and dividing the fundamental tissue into two portions: the inner, included within the circle of fibro-vascular bundles, is the *pith* or *medulla* (Fig. 46 *B m*); and the outer, lying between this circle and the epidermis, the *cortex* (Fig. 46 *B r*). Those portions of the fundamental tissue which lie between the fibro-vascular bundles in the circle, and which therefore connect the pith and the cortex, are called the *medullary rays*. This arrangement occurs principally in Dicotyledons and Gymnosperms.

Bundles which belong exclusively to the stem are termed *cauline bundles;* they are such bundles as cannot be regarded as direct prolongations of those of the leaves. They are present in the Ferns and the Rhizocarps, in the Lycopodieæ, and in Selaginella; but they occur only rarely in Phanerogams, and then in aquatic plants, such as Hippuris, Callitriche, Myriophyllum, Elodea, Naias.

Roots differ so widely from stems and leaves in the structure and arrangement of their fibro-vascular bundles, that the consideration of them must be postponed for the present.

A well-developed fibro-vascular bundle consists of two kinds of permanent tissue: the *Xylem* or *Wood* and the *Phloëm* or *Bast.* Excepting when special circumstances give rise to other conditions, the walls of the wood-cells tend to become lignified and their cavities to be filled with air: these cells constitute the firm but brittle portion of the bundle. In the phloëm there is a tendency to the formation of softer and more flexible cell-walls, which are but slightly lignified, and the cells retain their sap. Those fibro-vascular bundles which consist only of these two forms of tissue are incapable of any further growth, and are said to be *closed;* whereas those which possess in addition a layer of generating-tissue (meristem), the *Cambium,* throughout their whole length, which, by the active growth and division of its cells, increases the bulk of the xylem and of the phloëm between which it lies, are said to be *open.*

The xylem (wood) of a fibro-vascular bundle (so long as it has not been added to by the activity of the cambium) consists of the three following elements:

(1.) True *vessels* (*tracheæ*, *ducts*): they are formed from rows of superimposed cells, the transverse walls of which have been more or less absorbed. According to the mode in which their longitudinal walls have been thickened, they are distinguished as spiral, reticulate, annular, scalariform, or pitted vessels (Fig. 47 *B s s′* and Fig. 25 *s*) (Fig. 47 *B t t′* and Fig. 23 *C*): their contents are air or water.

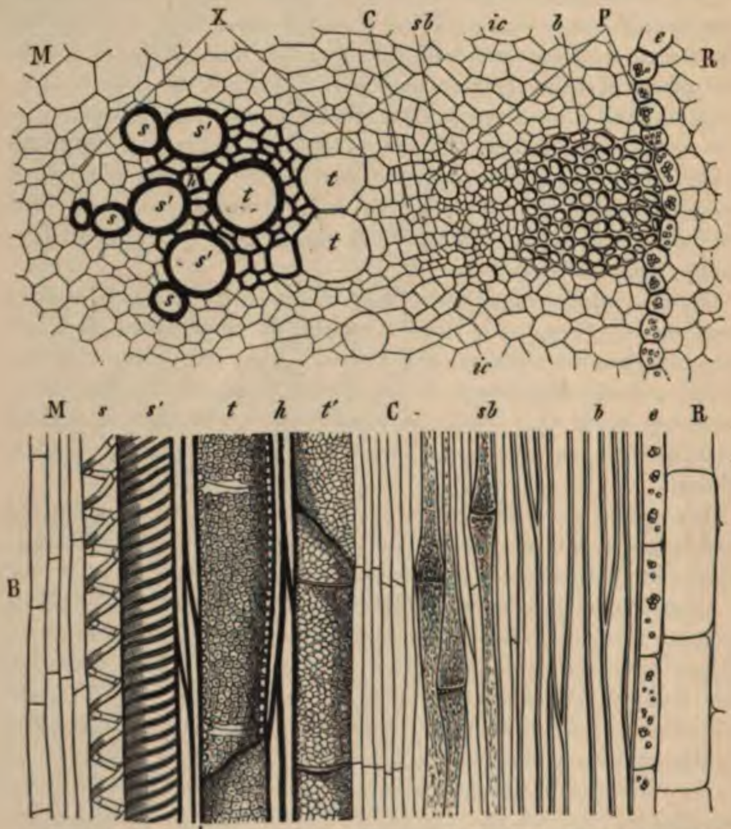


Fig. 47.—A transverse section of an open fibro-vascular bundle in the stem of the Sunflower. *M* Pith. *X* Xylem. *C* Cambium. *P* Phloëm. *R* Cortex; *s* small, and *s′* large spiral vessels; *t* pitted vessels; *t′* pitted vessels in course of formation; *h* wood-fibres; *sb* sieve-tubes; *b* bast-fibres; *e* bundle-sheath; *ic* inter-fascicular cambium. *B* Radial vertical section through a similar bundle (somewhat simplified) lettered like the former.

(2.) Much lengthened, narrow, prosenchymatous cells; the *wood-cells* or fibres (Fig. 47 *B h* and Fig. 23 *B*).

(3.) Parenchymatous cells, forming the *wood-parenchyma*, and still containing protoplasm; frequently they are wanting.

The bast in like manner consists of:

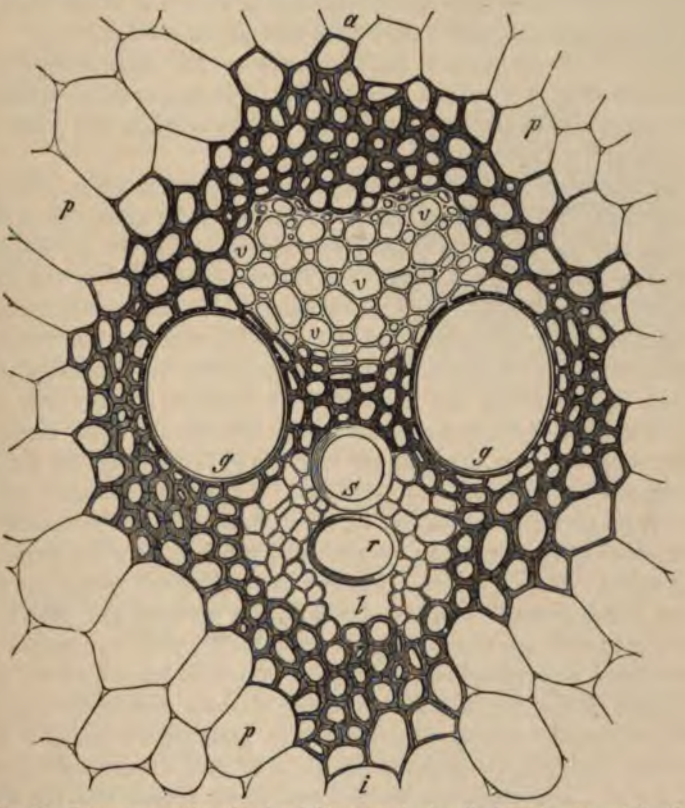


FIG. 48.—Transverse section of a closed fibro-vascular bundle from the stem of *Zea Mais* (× 550): *a* outer, *i* inner side with reference to the axis of the stem; *p* parenchymatous ground-tissue; *g g* two large pitted vessels; *s* spiral vessel; *r* ring of an annular vessel; *l* air-space formed by rupture, surrounded by thin-walled wood-cells. Between the two vessels *g g* lie smaller reticulated vessels and vessels with bordered-pits. These elements constitute the xylem: the phloëm is composed of soft bast, *v*. The whole bundle is surrounded by a sheath of thick-walled, lignified, prosenchymatous cells belonging to the ground-tissue. (After Sachs.)

(1.) Vascular elements, the *sieve-tubes*, which have thin side-walls, but thick transverse septa, perforated by closely-set, open canals; they are filled with albuminous substances (Fig. 47 *B sb*).

(2.) Prosenchymatous elements, the *bast-fibres*, which are often long and much thickened, but flexible.

(3.) Elongated, prismatic, thin-walled cells (*Phloëm parenchyma*): these cells remain in the primitive condition in which all the cells of the phloëm originally were: they are also termed *cambiform*, and, together with the sieve-tubes, are known as *soft bast*, in contradistinction to the thick-walled bast-fibres, the *hard bast*.

These different kinds of cells are more or less fully represented in a section of a fibro-vascular bundle, their proportional number varying with the part from which the section is taken, and with the nature of the plant.

By far the most frequent arrangement is, that the xylem and the phloëm in each bundle lie one behind the other on same radius, the xylem being nearer to the centre of the stem, while the phloëm lies towards the periphery (Figs. 45, 47, 48, 50). This is the case both when the bundles form a circle and when they are scattered, when they are open and when they are closed. As the bundles bend outwards into the leaves without any twisting, and are distributed in one plane, the phloëm of the bundles lies towards the under surface of the leaf and the xylem towards the upper surface. Exceptions to these relations are found in cylindrical leaves and in many petioles, in which the twisting of some of the bundles gives rise to an arrangement similar to, but sometimes more complicated than, that of the stem. In open bundles the cambium lies between the xylem and the phloëm. The annular and spiral vessels always form the innermost portion of the xylem towards the centre of the stem; and the outer portion, towards the phloëm, consists of reticulated and pitted vessels, which are the largest of all the elements of the xylem. The grouping of these vessels as regards each other, the woody fibres, and the parenchyma cells, is extremely various; those shown in Figs. 47 and 48 are only some examples. The innermost annular and spiral vessels are the first formed in each fibro-vascular bundle, and already exist before the contiguous portion of the stem has attained its definitive length; they grow with its growth, and, since they cannot undergo any further transverse division like the other elements of the bundle which are as yet undifferentiated, they consist of the longest cells. In the phloëm the bast-fibres usually lie nearest to the periphery, and the sieve-tubes, which are generally conspicuous by their larger apertures (in transverse section), are scattered in the soft bast (Figs. 47 and 48).

The following deviations from this, which is the commonest arrangement (*the collateral*) of the phloëm and xylem, as well as of their constituents, may be mentioned:

In many plants, *e.g.*, Gourds and Lycium, a second layer of phloëm is found within the xylem: in most Ferns the phloëm completely encloses the xylem, forming a ring (*concentric arrangement*), and several groups of spiral vessels lie within the xylem, from which the development of the xylem proceeds.

The fibro-vascular bundles of the root differ most widely from the structure above described. It is, in fact, impossible to speak of separate bundles in the root; a cylindrical mass of fibro-vascular bundles, sometimes hollow and containing a pith, occupies the axis of the root (Fig. 20). In this, several xylem bundles are regularly distributed (Fig. 49 *A g*), and alternating radially with them lie an equal number of phloëm bundles (Fig. 49 *A b*). In Dicotyledons the number of these bundles is small, usually 2, 3, or 4, rarely 5 to 8; in the Monocotyledons it is usually larger. In each xylem bundle the spiral vessels, which are here the oldest constituents, lie nearest to the periphery. The external layer of the fibro-vascular cylinder is known as the *pericambium*, and remains for a long period capable of development and growth. The rudiments of the lateral roots are usually formed from this pericambium in Phanerogams, exactly opposite to the xylem bundles (except in Grasses and Umbellifers), but in Cryptogams (except Equisetum) from cells of the endodermis; thus, irrespectively of the adventitious roots which are formed later, there are as many rows of lateral roots on a main root as there are xylem bundles in the fibro-vascular mass. The lateral roots, in the course of their development, have to penetrate the cortex of the mother-root

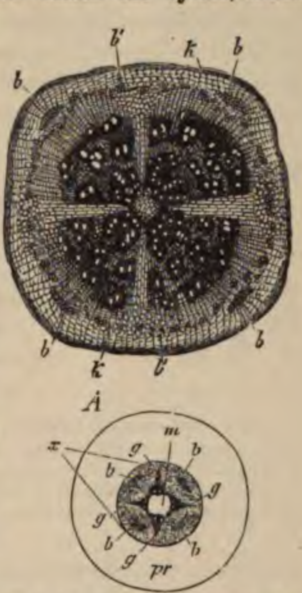


FIG. 49.—*A* Transverse section of a young root of *Phaseolus multiflorus*; *pr* cortical fundamental tissue; *m* pith; *x* fibro-vascular cylinder; *g* primary xylem bundles; *b* primary phloëm bundles. *B* Transverse section of an older root of the same plant, which is increasing in thickness: *b'* secondary bast; *k* cork—slightly magnified. (After Sachs.)

see p. 23, Fig. 20): their fibro-vascular bundles are in direct connection with those of the mother-root.

§ 26. **The Growth in Thickness** of the stem and roots is effected in most Gymnosperms and Dicotyledons by the continuous activity of the cambium of their open bundles. These are arranged in a circle in a transverse section of the stem (Fig. 50 *A*): the commencement of growth in thickness is preceded by tangential divisions in the fundamental tissue (Fig. 47 *A ic*) which lies between the bundles; this gives rise to cambium which becomes continuous with that of the fibro-vascular bundles. A closed hollow cylinder is thus formed, which appears, in a transverse section, as a ring, the *cambium-ring* (Fig. 50 *B c*) completely separating the pith from the cortex; it consists of two portions corresponding to its mode of origin; *fascicular cambium, i.e.*, the cambium belonging to the fibro-vascular bundles, and the *inter-fascicular cambium, i.e.*, that which is formed between the bundles in the primary medullary rays.

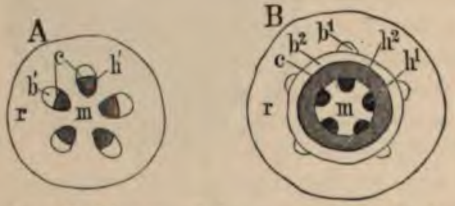


FIG. 50.—Diagrammatic transverse sections of a stem which grows in thickness. *A* Very young: there are five isolated bundles; *m* pith; *r* cortex; b' primary bast; h^1 primary wood; *c* cambium. *B* After growth in thickness has commenced: h^2 secondary wood; b^2 secondary bast.

A cambium-ring is likewise formed in roots which increase in thickness; the cells which lie between the individual xylem-bundles and internally to each phloëm-bundle are transformed into cambium-cells by division, and the separate groups of these cells become connected externally to the xylem-bundles. Thus a ring is formed which lies outside the primary xylem-bundles and inside the primary phloëm-bundles (Fig. 49 *B*).

The cells of the cambium-ring, in the stem and root alike, constantly undergo both tangential and radial division, so that the number of the cells increases in the radial direction as well as in the circumferential: the growth of these cells produces an extension of the organ in both these directions. Of the cells thus formed, those lying on the inner side of the cambium are transformed into the elements of the wood (Fig. 50 *B* h^2), those on the outer side, into the elements of the bast, while the cells of the intermediate zone continue to be capable of dividing. The activity of the cambium thus gives rise to *secondary* wood and *secondary* bast, as distinguished from the *primary* constituents of the bundle, which existed previously to, and independently of, the activity of the cambium. The primary wood of the bundle is thus the innermost part of it, and usually projects into the pith, particularly when the primary bundles lie rather far apart; it then constitutes what is termed the *medullary sheath* (Fig. 50 *B* h^1 and 52 *m s*).

The elements composing the secondary wood correspond in general with those of the primary xylem, but they present certain peculiarities. First of all it may be observed that they are arranged in radial lines, at any rate in the first instance, because all the elements which have originated from a single cambium-cell lie on one radius. The cambium-cells are of an elongated form, and are disposed somewhat prosenchymatously in such a way that their oblique septa are distinctly visible only in a tangential section, that is, in profile (Fig. 51 *A*). It is by the transformation of their daughter-cells, which exactly resemble the cambium-cells, that the different cells which compose the secondary wood and bast are formed. The secondary wood of trees consists of the following elements:

(1.) Of *Vessels*, which are usually provided with pits (frequently bordered-pits) on their longitudinal walls; their diameter is greater than that of the other elements, their constituent cells are usually of the same length as the cambium-cells. The transverse walls are either wholly absorbed, or only perforated. In some wood, as that of the Lime, delicate spiral thickenings are found in addition to the pits on the longitudinal walls: they can be distinguished from true spiral vessels by the delicacy of their structure and by the fact that injury does not cause a separation of the spiral thickening from the wall.

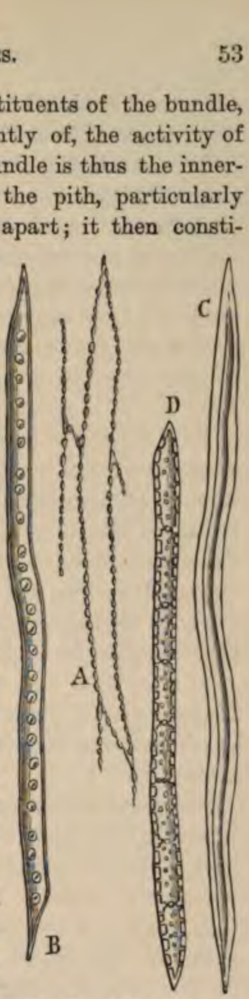


FIG. 51.—*A* Cambium-cells seen in a tangential section. *B* Tracheïde seen from outside. *C* Libriform fibre; and *D* a group of cells from the wood-parenchyma seen in section, from the Oak; isolated by maceration.

(2.) Of *wood-fibres* which are much elongated, almost always longer than the cambium-cells, and their transverse septa are more oblique: the pointed ends of the individual cells also grow in between each other. The walls of the woody fibres are sometimes unpitted or have small slit-like pits (Fig. 51 *C*), *libriform fibres;* sometimes they are pitted like the walls of the vessels (Fig. 51 *B*), *tracheïdes;* they are not perforated.

(3.) Of *Wood-parenchyma* which is formed by the repeated transverse division of the cambium-cells; the parenchymatous cells produced from each cambium-cell form a group which is bounded by the oblique walls of the cambium-cell (Fig. 51 *D*). The walls of the wood-parenchyma-cells are thin, and bear large simple pits.

With reference to the very varied distribution of these different elements of fibro-vascular bundles, it may be particularly noted that in all Conifers true vessels and woody parenchyma (apart from the resin-ducts, § 28) are wanting: the medullary sheath, the primary xylem, of course contains annular, spiral, and reticulated vessels, but the secondary wood of these trees consists solely of tracheïdes, the walls of which bear the peculiar bordered-pits described in § 22 (Fig. 42).

In most trees and shrubs, and in the stems of the stronger herbaceous plants, the fibres generally form the greater part of the wood, and the vessels and woody parenchyma-cells are scattered among them.

Succulent stem-structures which increase in thickness, *e.g.*, the tubers of the Potato, contain in the wood formed from the cambium nothing but thin-walled, juicy, parenchymatous cells traversed by a few solitary vessels.

A transverse section of the wood of our timber-trees exhibits, even to the naked eye, a series of concentric layers known as the *annual rings.* These layers result from the fact that the wood formed in the spring is differently constituted from that which is formed in the summer; since the external conditions on which this difference depends gradually change in the course of a year, and during the winter no wood is formed, it is easy to imagine that in the ring of wood which represents one year's growth a gradual change of structure should be perceptible from within outwards, and that the limit between the ring of one year and that of another should be sharply defined. The anatomical cause of the distinctness of the annual rings is the same in all wood, namely, that the last layers of the wood formed in a year are much compressed, and therefore have a very small radial diameter (Fig. 53 *w*). In Conifers these layers are further distinguished by the fact that the spring-wood is formed of thin-walled cells (Fig. 53 *f*) and the autumn-wood of thick-walled cells (Fig. 53 *h*). In foliage-trees the number and size of the vessels diminishes in each annual ring from its inner to its outer limit. When this takes place very gradually the eye cannot detect any conspicuous difference between the spring and autumn-wood (as in the wood of the Beech, Lime, Maple, and Walnut); but some kinds of wood show a ring of conspicuously large vessels in the spring-wood, while in the autumn-wood there are numerous much smaller vessels (as in the wood of the Oak, Elm, and Ash).

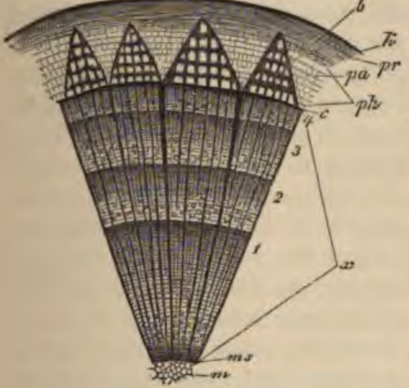


FIG. 52.—Part of a transverse section of a twig of the Lime, four years old (slightly magnified): *m* pith; *ms* medullary sheath; *x* secondary wood; 1 2 3 4 four annual rings; *c* cambium; *ph* bast; *pa* primary medullary rays; *b* bast-fibres; *pr* primary cortex; *k* cork.

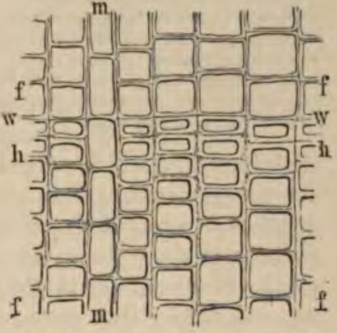


FIG. 53.—Transverse section of Fir-wood at the junction of two annual rings: *m* a medullary ray—all the other cells belong to the wood; *f* loose spring-wood; *h* dense autumn-wood; *w* the limit between the autumn-wood and the spring-wood of the following year; between *h* and *w* is the flattened limiting layer (× 250).

Besides the elements which have been already considered, the wood includes certain parenchymatous cells which are elongated in a radial direction and are known as the *medullary rays*. These appear in a transverse section as radial stripes, in a radial section as radial bands of small height, and in a tangential section as elliptical groups of cells (Fig. 54), surrounded by the elongated elements of the wood; they consist of parenchymatous cells much elongated in the radial direction (Fig. 53 *m*), but very small in the tangential and vertical directions. These medullary rays, like the constituents of the wood, are developed from the cambium both towards the centre and towards the circumference, so that each medullary ray runs from the wood through the cambium into the bast. When once a group of cambium-cells has begun to produce a medullary ray, it continues to do so, and the greater the circumference attained by the wood, the greater is the number of the points at which the formation of medullary rays begins in the cambium, and the greater the number of medullary rays which penetrate the wood. Those medullary rays which extend inwards to the pith and outwards to the primary cortex, those, namely, which existed at the beginning of the thickening of the stem, are termed *primary*. These increase radially, in some plants by means of the whole of the inter-fascicular cambium, *e.g.*, in the Clematis; in others, on the contrary, by means of isolated portions of the inter-fascicular cambium, *e.g.*, in the Hornbeam. *Secondary* medullary rays are such as are formed at a later stage, and do not therefore extend to the pith, but end blindly in the wood. When the medullary rays, or at any rate some of them, are large, they are easily detected by the naked eye, as in the wood of the Beech and Oak.

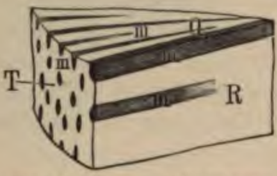


FIG. 54.—Diagrammatic representation of the course of the medullary rays; a segment cut out of the wood: Q Horizontal surface. *R* Radial surface. *T* Tangential (external) surface of the wood; the shaded portions are the medullary rays.

The wood of many large timber trees frequently exhibits a striking difference between the older internal portion of the wood, the heart-wood (*duramen*), and the younger outer portion known as the sap-wood (*alburnum*). This arises from changes undergone in the course of years by the mature wood. The altered heart-wood always contains less water, has no starch in its parenchymatous cells, and is often darker in colour, *e.g.*, the Pine, Larch, and Oak.

The secondary bast formed from the cambium never attains so considerable a size as the wood; it consists of sieve-tubes, bast-fibres, and parenchymatous cells in varying order, very rarely showing any regularity; sometimes the bast fibres are in layers, so that they can be removed in large connected sheets, as in the Lime. The formation of annual rings does not take place. The medullary rays, as mentioned above, traverse the bast to an extent corresponding to their development in the wood. In many trees the cells of the medullary rays, and other cells also, in the bast, become sclerenchymatous; for instance, in the Beech, where they project from the surface of the dry cortex which is in contact with the cambium, in the form of sharp teeth. As the cambium-ring is constantly increasing in circumference, the bast which surrounds it necessarily experiences considerable tension, particularly in the outer portion. This tension naturally affects chiefly the parenchymatous elements which are still capable of growth while the bast-fibres are no longer capable of any modification; hence the medullary rays are often seen to be much expanded towards the circumference (Fig. 52 *pa*).

The tissues lying externally to the cambium are generally spoken of collectively as "cortex"; it will be well, therefore, to designate the bast which has been formed by the cambium as *secondary cortex*, in order to distinguish it from the *primary cortex* which lies externally to it and belongs to the fundamental tissue. The cells of the cambium-ring are rich in protoplasm and tear very readily, especially when they are actively growing and dividing; consequently the "cortex" can be easily stripped from the wood.

Many woody plants, of which, however, only a few are indigenous to this part of the world, depart from the general type here described both in the origin and in the mode of growth of their cambium-ring. The aborescent Liliaceæ (Yucca and Dracæna) may be mentioned as being the only Monocotyledons of which the stems increase in thickness. As the fibro-vascular bundles are all closed, there is no cambium, and the increase in circumference is possible only by a new formation, in a zone of the fundamental tissue, both of isolated, closed, fibro-vascular bundles and of fresh fundamental tissue.

§ 27. The term **Fundamental Tissue** (ground-tissue) includes all the mass of tissue which does not form part of the fibro-vascular bundles or of the epidermis (Fig. 24 *g*). Various forms of cells and of tissues occur in it, and those parts of it in particular which lie in immediate contact with other tissue-systems are frequently remarkable for peculiarities of structure.

Those specially modified forms of fundamental tissue which occur in close connection with the epidermis are included under the term *Hypoderma*. One form frequently occurs in the stems and leaf-stalks of dicotyledonous plants which is known as *Collenchyma* (Fig. 55 *cl*), a tissue, the cells of which are narrow and elongated, with their walls thickened along the lines of contact, and capable of swelling-up considerably. In other cases the elements of the hypoderma are fibrous and sclerenchymatous, as in the leaves of Conifers.

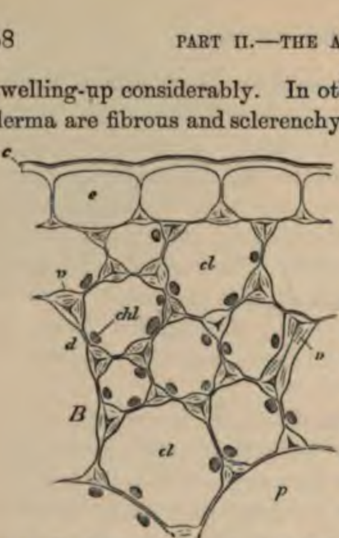


FIG. 55.—Transverse section of the leaf-stalk of a Begonia: Epidermis (*e*) and collenchyma (*cl*); the epidermis-cells are uniformly thickened on the outer wall where they adjoin the collenchyma, but are thickened like the collenchyma at the angles where three cells meet; these thickenings have great capacity for swelling; *chl* chlorophyll-corpuscles; *p* parenchyma-cell; *c* cuticle (× 550). (After Sachs.)

Bundle-sheath (Endodermis). This name has been given to the single layer of cells (belonging to the fundamental tissue) which forms a common investment to the fibro-vascular bundles in the stems of plants having an axial fibro-vascular cylinder, such as Hippuris and other aquatic plants, as well as in those of many with a normal arrangement of the bundles, such as certain Primulaceæ, Compositæ, Cyperaceæ, and some species of Equisetum. In the stems of most Ferns and some Equisetums, as well as in the petioles and stems of some few Phanerogams, each of the isolated fibro-vascular bundles is surrounded by a sheath (Fig. 47 *e*). It is invariably present in roots. The walls of these cells which are in contact are usually folded in a peculiar manner and are cuticularised.

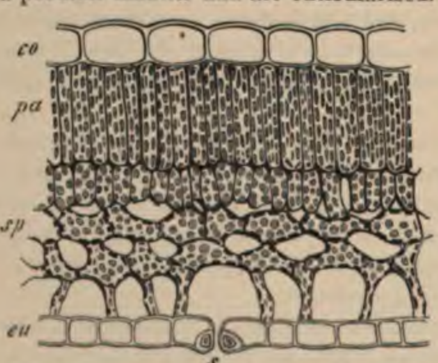


FIG. 56.—Transverse section of a Beech Leaf (× 350): *eo* epidermis of the upper surface; *eu* epidermis of the under surface; *pa* pallisade parenchyma; *sp* spongy parenchyma.

External sheath. This term is applied to such cells of the fundamental tissue as surround fibro-vascular bundles and have undergone special modification. The closed bundles of Grasses (Fig. 48) and of many Monocotyledons are surrounded by an investment consisting of several layers of prosenchymatous cells.

The rest of the fundamental tissue, the *complementary tissue*, consists (with the exception of the prosenchymatous ground-tissue in the stems of Lycopodiaceæ, etc.) of thin-walled succulent parenchyma with intercellular spaces: the cells may contain chlorophyll-corpuscles, as in the case of leaves and of the cortex of stems, or the tissue may be colourless, as in the interior of succulent stems, in roots, and in juicy fruits.

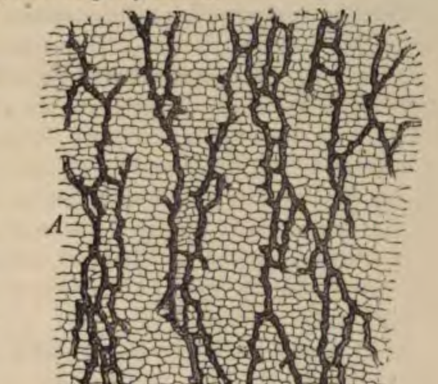


FIG. 57.—Laticiferous vessels in the phloëm of *Scorzonera hispanica*, tangential section. *A* Slightly magnified. *B* A small portion highly magnified. (After Sachs.)

The chlorophyll-containing ground-tissue of leaves is usually of a different texture at the two surfaces of the leaf; it is in consequence of this that the two surfaces differ somewhat in colour.

The tissue of the upper surface consists principally of *pallisade parenchyma*, that is, of narrow, elongated cells, arranged perpendicularly to the surface and having very small intercellular spaces (Fig. 56 *pa*); the parenchyma of the under surface, on the contrary, the *spongy parenchyma*, is formed of cells which are irregularly arranged, and are separated by large intercellular spaces (Fig. 56 *sp*).

The cells of the pith of woody plants generally all die, as in Sambucus (Elder), or at any rate most of them do so.

Sclerenchymatous cells occur in the most different parts of the fundamental tissue; they may be isolated, as, for instance, in the flesh of Pears and in the cortical parenchyma of many trees, or united to form a considerable mass of sclerenchymatous tissue, as in the shell of many fruits, as the hazel-nut, and the stone of others, as the plum.

§ 28. **Internal Receptacles for Secretions.** In the fibro-vascular system, as well as in the fundamental tissue, besides the forms of tissue hitherto described, there are found other structures which serve to secrete and to transmit certain substances which do not occur throughout the plant: these structures traverse both the internal tissue-systems, so they cannot be regarded as belonging especially to either, but must be considered separately. According to their mode of origin, these receptacles may be either isolated closed cells containing nothing but the matter secreted, or they may be vascular structures, formed by the fusion of elongated cells by the absorption of their walls; or, again, they may be intercellular spaces, cavities filled with secretion which have been formed either by the absorption of a mass of tissue (*lysigenous*) or by the separation from each other of uninjured cells (*schizogenous*) (see § 23). They may be arranged in the following order, according to the nature of the secretion:

(1.) Crystals or clusters of crystals are frequently found in certain cells, particularly in the fundamental tissue of Monocotyledons and in the bast of many trees.

(2.) Cells filled with mucilage occur in the Malvaceæ, in the cortex of the Elm and Firs, in the tubers of the Orchideæ; mucilage also occurs in lysigenous intercellular spaces in the Cacteæ; cherry-gum, which is formed by a gradual transformation of groups of cells, must be included here.

(3.) The milky juice (latex) which flows from many plants when they are cut, derives its milky appearance from minute solid particles which are suspended in watery fluid, constituting a sort of emulsion; the milky juice frequently contains caoutchouc; sometimes, as in Chelidonium, it is yellow. This milky juice is found in different vessels in the different families of plants.

(*a.*) In the Cichoriaceæ (as the Dandelion and Scorzonera), the Papaveraceæ, and Campanulaceæ, it is contained in the *laticiferous vessels;* they are straight or branched, anastomosing rows of cells, the transverse walls of which are absorbed or perforated (Fig. 57).

(*b.*) In the Euphorbiaceæ (*e.g.*, the Spurges), the Urticaceæ, and Asclepiadeæ, the milky juice is contained in closed cells, which are much branched and extend throughout the whole plant. These *laticiferous cells* are already present in the embryo, while it still consists of only a few cells, and they grow with its growth without undergoing any division.

(*c.*) The milky juice is contained in cells of small dimensions, which are not unfrequently arranged in rows; this is the case in the Maple, in Sambucus (Elder), where these cells are visible as red lines at the circumference of the dried-up pith, in the Convolvulaceæ, where the milky juice contains much resin, in *Isonandra Gutta*, of which the inspissated milky juice forms Gutta percha.

All these forms of laticiferous vessels occur principally in the cortex and phloëm, but they sometimes occur also on the inner side of the fibro-vascular bundles of the plants in question. A great number of very important products, valuable in medicine and the industrial arts, are derived from the latex: thus Caoutchouc (India rubber) is the dried milky juice of *Siphonia elastica*, one of the Euphorbiaceæ, and Opium is the milky juice of the unripe capsules of the Poppy, *Papaver somniferum*.

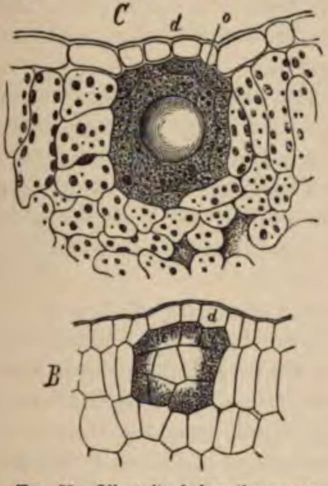


FIG. 58.—Oil-cavity below the upper surface of the leaf of *Dictamnus Fraxinella* (× 320). *B* At an early stage: *C* mature; *c* mother-cells of the cavity before their absorption; *o* a large drop of ethereal oil. (After Sachs.)

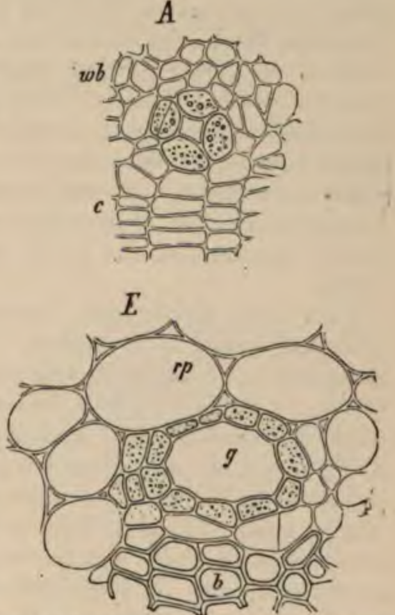


FIG. 59.—Resin-passages in the young stem of the Ivy (*Hedera Helix*), transverse section (× 800). *A* An early, *E* A later stage; *g* the resin-passage; *c* the cambium; *wb* the soft bast; *b* bast-fibres; *rp* cortical parenchyma. (After Sachs.)

(4.) *Resins and ethereal oils*, not unfrequently combined, occur:

(*a*.) In *cells*, in the Laurineæ, *e.g.*, Camphor; in the Zingiberaceæ, Acorus, and other plants; the solitary resin-cells in the wood of the Silver Fir may be mentioned here.

(*b*.) In *intercellular spaces*, which may be of lysigenous origin and are then usually of a spherical form; these were formerly designated glands (Fig. 58). The oil of the Citron, Orange, Rutaceæ, Myrtaceæ, is contained in such cavities, as well as that of the leaves of Hypericum, which present in consequence a number of transparent spots.

The other intercellular spaces which contain oil or resin are of schizogenous origin; that is, they are formed by the separation from each other of certain cells surrounding the intercellular space (which is usually elongated in form), and differing from the rest of the tissues in their arrangement and mode of division (Fig. 59). To these belong the oil cavities which traverse the primary cortex and phloëm of the Compositæ, and the gum-resin-ducts of the Umbelliferæ and their allies, in which the resin is mixed with gum: also the resin-ducts of the Terebinthaceæ, Simarubeæ, and Coniferæ, which contain a *Balsam*, *i.e.*, a solution of resin in an ethereal oil. In the Coniferæ (among which resin is wholly absent from one genus only, namely Taxus), they are found in the leaves, the arrangement varying with the species, and they pass from them into the primary cortex; they also run longitudinally through the wood and transversely in the larger medullary rays. Lysigenous resin-receptacles of a spherical form are formed secondarily in several species, *e.g.*, the Larch, in the primary and secondary cortex.

§ 29. **The Epidermis.** In the lowest forms of plants the epidermal system is not sharply defined from the fundamental tissue, and is, properly speaking, only the outermost layer of that tissue. In the higher plants there is usually a true epidermis (Fig. 45 *e*); this envelopes most annual plants, and generally consists of a single layer of cells, which are in close juxtaposition (with the exception of the stomata) without any intercellular spaces: it may be easily stripped off from certain parts of many plants (*e.g.*, the scales of the Onion and the leaves of Begonia) as a thin transparent membrane. In some special cases, *e.g.*, the leaves of Ficus and Peperomia, the primitively single layer of the epidermis divides into two or more layers, of which the outer layer alone has the appearance of a true epidermis. Sometimes the cells of the epidermis differ very slightly from those of the internal tissue, as in the roots and leaves of many water-plants; but the difference between the epidermis and the tissues which lie beneath it, in the case of the stems and leaves of terrestrial plants, is well marked, and the epidermis is usually further distinguished by certain peculiar structures, such as stomata and hairs. The epidermal cells but seldom contain chlorophyll, but, on the other hand, they often contain other colouring-matters in solution. In those parts of plants which grow to a considerable length, their form is usually elongated; in broad leaves it is commonly tabular. The side walls have very frequently an undulating outline, so that the adjoining cells fit into each other. The external wall is usually much more thickened than the other walls; its outermost layer is always cuticularised, and is called the *cuticle;* it is clearly defined from the inner layers, which are also more or less cuticularised (Fig. 60), and it extends continuously over the whole of the epidermis. It has a tendency to form thickenings projecting outwards from the surface. Particles of wax are included in the cuticle of many terrestrial plants which protect their surface from being wetted by water. This wax often appears on the surface in the form of small granules, rods, or flakes, and then forms a bluish bloom, which is easily wiped off, or sometimes a considerable mass, as in the fruits of *Myrica cerifera* and the trunks of some Palms (*Ceratoxylon andicola* and *Klopstockia cerifera*).

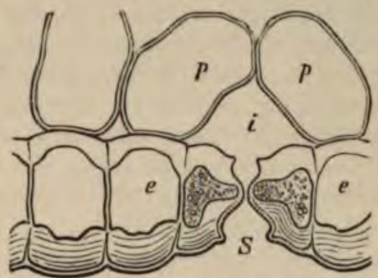


FIG. 60.—Epidermis (*e*) with a stoma (S) from a cross section of a leaf of *Hyacinthus orientalis* (× 800): *p* parenchyma of the fundamental tissue; *i* an air-cavity.

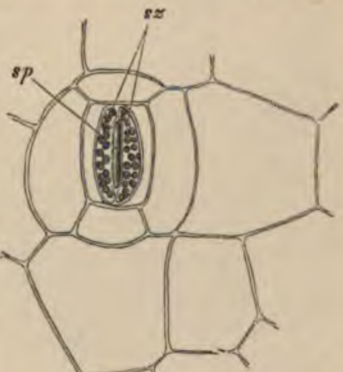


FIG. 61.—Stoma of a leaf of *Commelina cœlestis*, surface view (× 300): *sp* opening; *sz* the two guard-cells

The *Stomata* are organs which here and there interrupt the continuity of the epidermis and permit communication between the air contained in the intercellular spaces and in the vessels, and the external atmosphere. Each stoma consists of two peculiarly modified epidermal cells called *guard-cells;* these, when seen from the surface, appear usually of a half-moon shape (Fig. 61 *sz*) and surround the opening of the stoma. This leads to the *air-cavity* (Fig.

60 *i*), a large intercellular space between the epidermis and the underlying tissue, which communicates with the other intercellular spaces. The whole stoma originates thus: a young epidermis-cell divides into two, the two guard-cells; these are separated by a septum, which is at first simple, but which subsequently splits. The size of the opening may be increased or diminished by the action of external influences, and this is effected by changes in the form of the guard-cells. Stomata are found on almost all parts of terrestrial plants which are above the ground, and are particularly abundant on leaves (as many as 600 to the square millimetre), they are usually wanting in submerged organs, and are always absent from roots.

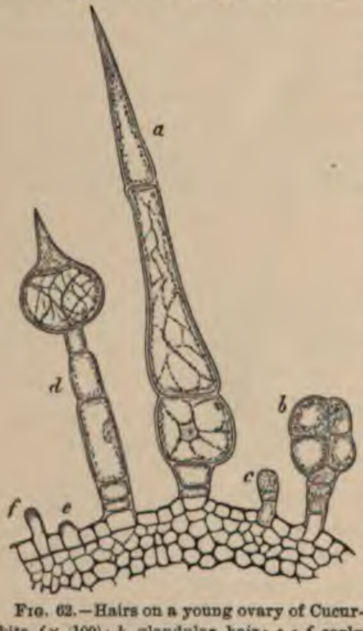


FIG. 62.—Hairs on a young ovary of Cucurbita (× 100); *b* glandular hair; *c e f* early stages of development.

Hairs are products of the epidermis, and are generally formed by the outgrowth of single epidermal cells. They may remain unicellular, as in the case of the root-hairs which form the velvety covering of young roots, and of the hairs on the outer coat (testa) of the seed of Gossypium, which constitute Cotton; or they may undergo division so that they consist of a row of cells (Fig. 62 *a*, *d*); or again, the outgrowth from the epidermal cell may undergo divisions in two or more directions, in consequence of which either a layer of cells is found, as in the case of the scales (*ramenta*) on the leaves of Ferns, or a mass of cells, as in the case of the stiff hairs on the fruits of Thistles and similar plants. If a mass of cells be formed at the apex of a hair, or if the cells near the apex are much larger than the rest, it is called a *glandular hair* (Fig. 62 *b*). In many cases the contents of the hair-cells disappear at an early stage, as in Cotton, and are replaced by air. Sometimes the membrane becomes greatly thickened, and often contains deposits of considerable quantities of lime and silica. The stinging hairs of Nettles and other plants secrete an acrid fluid which, as their points break very easily, enters the object touching them.

The *Glands*, the secreting organs of the epidermis, are peculiar in that the secretion (which is usually of a sticky nature) makes its appearance in the substance of the cell-wall under the cuticle: it causes the cuticle to separate from the remainder of the cell-wall, and finally ruptures it. Secretion takes place frequently over the general surface of the epidermis, as in young twigs of the Birch, or over certain circumscribed areas of it, as the teeth of the leaves of Prunus, Salix, and other plants, and the *nectaries* of flowers, or at the apex of glandular hairs, as in *Primula sinensis:* the *colleters* which clothe the young organs in the winter-buds of trees, and which cover the unfolding leaves with their secretion, are also glandular hairs of this kind. Digestive glands, which secrete a fluid capable of dissolving various foreign bodies, are peculiar to certain plants; they are found in the "tentacles" of Drosera, etc. (Fig. 72).

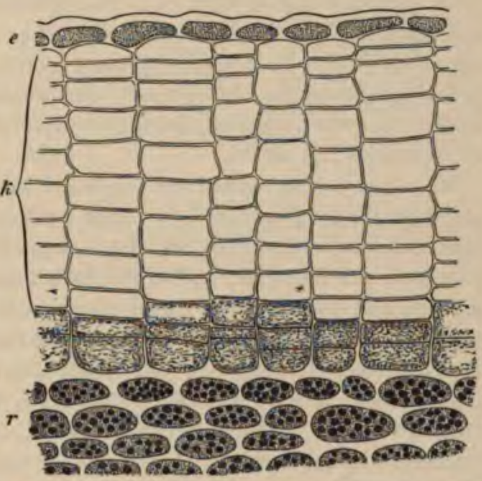


FIG. 63.—Cork of one-year's shoot of *Ailanthus glandulosa* (trans. sect. × 350); *e* the dead epidermis, *k* cork cells, the inner layers meristematic (phellogen); *r* primary cortex.

In those parts of plants which grow in thickness, such as the stems and branches of trees, the tubers of the Potato, and napiform roots, the epidermis is usually unable to keep pace with the increase of the circumference, and it ruptures: a new protective tissue is usually formed from the cortical fundamental tissue, which is termed the *Cork* or *Periderm*. This consists of tabular cells arranged in rows perpendicularly to the circumference of the organ: their walls are converted into cork, and are scarcely permeable to water: they usually contain nothing but air (Fig. 63 *k*). The cork-cells are formed by tangential divisions taking place in the cells of a special meristem, the *Phellogen*, and lie externally to it: frequently parenchymatous cells containing chlorophyll are formed in a similar manner from the phellogen, and lie internally to it: these are known as *Phelloderm*.

A formation of cork is wholly absent in only a very few woody plants, as the Mistletoe and a species of Maple (*Acer Pennsylvanicum*); in Euonymus it occurs only in branches of several years' growth. It usually takes place in one-year's shoots towards the end of summer, so that their originally green colour is changed to brown. This periderm, which serves as a substitute for the decaying epidermis, and which may be termed *primary*, is usually formed in the outermost layer of the cortex in immediate contact with the epidermis; in rare cases the epidermis itself is transformed into phellogen (in Salix and the Pomaceæ), or the phellogen originates in a more internal layer of the cortex (Leguminosæ, Larch, Ribes), or even in the phloëm (as in the Grape-Vine). In consequence of the impenetrability to water which is characteristic of the cork-cells, all the tissues outside the periderm necessarily dry up, and these dried-up tissues, which may belong to different tissue-systems and include the most various forms of cells, constitute what is known as *Bark*. In roots the primary periderm is always formed in the pericambium; consequently the whole of the cortex, which is often of great thickness, is transformed into bark and is thrown off (compare Fig. 49 *B*).

When the primary periderm originates in the outer layers of the cortex (or in the epidermis), it forms for many successive years the external investment of the branch; it may attain considerable thickness, as in the Cork-oak, and at the same time exhibit an alternation of dense and loose layers (*e.g.*, the Birch, in which the layers may be peeled off in thin white sheets); sometimes (as in *Acer campestre* and the Cork-elm) it forms wing-like projections from the angles of the branches. In a few trees, as the Silver Fir, this primary periderm persists for some years, or, as in the Beech, during the whole life of the tree; the outer cork-cells split off as the trunk of the tree increases in thickness, while the phellogen, growing and extending in a tangential direction, gives rise to new layers. In most cases, after a few years, new secondary layers of periderm are formed in the deeper layers of tissue, causing, naturally, the production of a very considerable bark. If the new secondary layers of periderm occupy only a part of the circumference, and their margins are in contact with the periderm which has been previously formed, a scaly bark is formed, that is, isolated patches of tissue are transformed into bark. This bark is stretched and torn by the increasing size of the trunk, and the scales of it may be shed, as is the case in the Plane, or they may adhere one upon the other, as in the Pines and Larches, or remain connected by the bast-fibres in long strips, as in Robinia. When, on the other hand, the primary periderm has been formed in the deeper layers of the cortex, the secondary periderm often forms complete concentric rings; thus hollow cylinders of the cortex are transformed into bark (ringed bark). The longitudinal rupture of this kind of bark is effected by the bast-fibres enclosed in it, *e.g.*, Vine, Clematis, and Thuja.

There are in the periderm organs corresponding to the stomata of the epidermis, and serving, like them, to admit air to the living portion of the cortical tissue; these are the *Lenticels*. They are usually circumscribed circular areas of the periderm where the cork-cells formed in the course of the summer are not arranged closely together, but are separated by intercellular spaces. In winter the lenticels are closed by ordinary cork-cells. They are most easily detected in branches of one year's growth, where they are to be seen in the summer in the form of brownish or whitish specks under the places where the stomata occur in the epidermis. These spots are commonly the starting-points of the formation of cork. In many trees, as the Birch, the lenticels become much extended in width by the growth of the branch in circumference. When the cork-layer is very thick, as in the Cork-oak, the lenticels form deep canals filled with a pulverulent mass of cells.

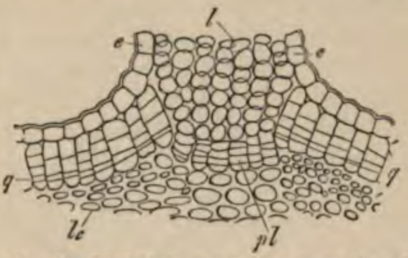


FIG. 64.—Lenticel in the transverse section of a twig of Elder (× 300): *e* epidermis, *q* phellogen, *l* cells and *pl* the phellogen of the lenticel, *lc* cortical parenchyma containing chlorophyll.

In woody plants the falling off of the leaves breaks the continuity of the epidermis. This process is induced by the formation in the autumn of a zone of peculiar tissue at the base of the leaf, the cells of which become separated along one plane by the splitting of the common walls, so that the cells remain uninjured. Cork is subsequently formed under the layer of cells covering the portion of the leaf which remains attached: the cork formed here becomes continuous with the periderm which invests the branch.

§ 30. **The Primary Meristem and the Apical Cell.** The growing end or apex of an organ, such as a root or a stem, is called the *growing-point* (*punctum vegetationis*). In roots it can be readily distinguished on account of its freedom from colour, and it will be seen to be enveloped by a transparent mass of tissue forming the *root-cap* (see § 7). In stems the growing-point is invested by the young leaves. In the growing-point the different forms of cells and systems of tissue which have just been described are not yet present; it consists of a tissue, the cells of which are all capable of division, rich in protoplasm, thin-walled, and in close juxtaposition, without any intercellular spaces: this is the *primary meristem.* Most leaves and fruits, and many other organs, consist, at the earliest stage of their development, wholly of primary meristem, which is subsequently transformed into the different forms and systems of tissue, so that none of the primary meristem remains. In those organs, on the other hand, which have a continuous apical growth, as most stems and roots, new primary meristem is constantly being produced proportionately to its transformation into permanent tissue, by the formation of new cells at the growing-point. At the apex of a root, the tissue of the root is formed backwards from the primary meristem, and the root-cap forwards; the external cells of the latter are constantly being worn off.

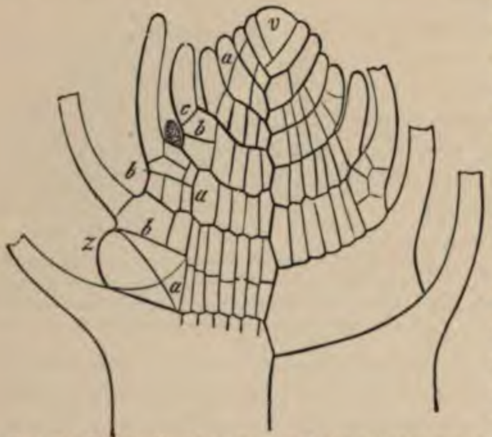


FIG. 65.—Longitudinal section through the apical region of a stem of *Fontinalis antipyretica*, a Moss growing in water (after Leitgeb): *v* the apical cell of the shoot, producing three rows of segments which are at first oblique and afterwards placed transversely (distinguished by a stronger outline). Each segment is first of all divided by the wall *a* into an inner and an outer cell; the former produces a part of the inner tissue of the stem, the latter the cortex of the stem and a leaf. Leaf-forming shoots arise beneath certain leaves, a triangular apical cell (*z*) being formed from an outer cell of the segment, which then, like *v*, produces three rows of segments; and each segment here also forms a leaf.

In Cryptogams this constant production of primary meristem is usually effected by means of a single cell, which occupies the apex of the growing organ, and is distinguished by its size and form; this is the *apical cell* (Fig. 65 *v*). This is the case in the higher

Thallophytes (but not in Fucus), in the Muscineæ, and in the Vascular Cryptogams (but not in Lycopodium, Isoëtes, some Selaginellas, roots of Marattiaceæ): in these exceptional cases no single apical cell is present. From this cell all the cells of the primary meristem, and consequently those of the whole mass of the plant, originate in the following way: it divides in regular succession into two; of these, the one remains exactly similar in form to the original apical cell, it increases in size, and then fulfils the functions of the apical cell in its turn; the other, known as the *segment*, by further subdivision (Fig. 65 *a b c*), forms a portion of the tissue of the organ to which it belongs. The whole mass of tissue is formed from the segments which are thus successively produced. The mode of the formation of the segments is very simple in some Algæ, where the terminal cell is divided only by transverse septa, so that the segments form a longitudinal row. The process is more complicated when the segments are cut off right and left alternately by oblique walls which intersect. It is still more complicated when, as in the stems of Mosses and of Ferns, the terminal cell is wedge-shaped or has the form of an inverted three or four-sided pyramid; segments are cut off from each of the sides by inclined walls in regular succession (Fig. 65). The root-cap is formed by segments which are cut off from the apical cell by walls parallel to its free surface.

From the foregoing account of the growing-point of Cryptogams it is evident that the tissues of such stems and roots as possess an apical cell must necessarily have a common origin. In the Vascular Cryptogams the commencing differentiation of the tissues in the primary meristem of these members can usually be observed close behind the apical cell. There is a distinct external layer of cells, known as the *dermatogen*, which is the primitive epidermis: within this are several layers of cells, termed *periblem*, from which the cortical tissues are derived; and in the centre is a cylinder of somewhat smaller cells, the *plerome*, from which the axial tissues, and most commonly the fibro-vascular bundles, will be formed.

In the Phanerogams, as well as in those Vascular Cryptogams which have been already mentioned as exceptions, the growing-point has no apical cell. It consists of a primary meristem which usually exhibits, in the stem at least, the above-mentioned differentiation into three systems. The tissues of the mature members have not, therefore, a common origin, as is the case when an apical cell is present, but each tissue-system is developed from the corresponding system of the primary meristem. In roots there is in many cases a fourth meristematic layer, the *calyptrogen*, from which the root-cap is developed, but the differentiation of the primary meristem is not so regular as it is in stems: in rare cases (Hydrocharis, *Pistia Stratiotes*) all four layers are present; in others (most Monocotyledons) the epidermis and the cortex are developed from a common meristematic layer, so that dermatogen and periblem cannot be distinguished; in others again (most Dicotyledons) the root-cap and the epidermis are derived from a common layer, and finally, in Gymnosperms, the primary meristem consists only of plerome and periblem.

§ 31. **Formation of Tissue in consequence of Injury.** When the internal tissues of most parts of plants are laid bare by injury, they are gradually covered by a formation of cork taking place in the outermost layer of cells which remain uninjured and capable of growth. This is easily seen in injured fruits, leaves, and herbaceous stems, in which the wounds that have been covered by a layer of cork are distinguished by a grey-brown colour. The process is very easy to observe in potato-tubers, for each portion of living tissue taken from one, if only prevented from drying too quickly, will soon be covered over the whole surface by a layer of cork precisely similar in structure to the ordinary rind. In plants in which the wood is well developed, cork is not immediately formed—particularly when the cambium is wounded or laid bare—but all the living cells which border on the wound give rise to a homogeneous parenchymatous tissue known as the *Callus*. If the wound is small the callus-cells proceeding from the different sides soon come into contact and close up into a single mass of tissue, which then gives rise to cork on its outer surface, and, joining the old cambium at the margins, forms a new layer of cambium, which fills up the cavity. If the wound is a large one, cork and new cambium are formed in the callus at the margins of the wound, and it is not wholly closed till after repeated rupture of the approaching cushions of callus. The wood exposed by the wound, which usually assumes a dark colour under the influence of the air, does not grow with that formed from the new cambium of the callus; hence inscriptions, for instance, which are cut in the cortex so as to reach the wood, though subsequently covered by a number of annual layers of wood corresponding to the number of years, may easily be found. A similar explanation accounts for the fact that the surfaces of the stumps of cut-off branches become overgrown; the callus first appears as a ring from the cambium exposed in the transverse section, and afterwards closes like a cap over the old wood. Foreign bodies —nails, stones, and stems of other plants—may thus become enclosed in the wood of a tree and be overgrown by it; the cortex, being forced against the foreign object by the pressure of the growing wood, splits, and the callus formed in the rent grows round the object, enclosing it and producing new cambium.

Stems of plants of the same species will grow together if they are in close contact; the callus formed by the cortex of both, coalesces and gives rise to a common cambium. On this depend the various modes of artificial grafting, in which branches or buds with a portion of the cortex are taken from a variety or an allied species and placed so that their cambium is in contact with that of a stem which serves as the stock, and subsequently they grow together.

PART III.

THE PHYSIOLOGY OF PLANTS.

CHAPTER I.

CHEMICAL PROCESSES IN PLANTS.

§ 32. **The Elementary Constituents of the Food of Plants.** All parts of living plants contain a considerable quantity of water: this forms not merely the principal constituent of the cell-sap, but also saturates the cell-walls, the protoplasm, in short, all organized structures. It is one of the peculiarities of organized structures that minute particles of water are interposed between the particles of solid matter of which they consist. By heating to 100° or 110° Cent., all the water contained in any part of a plant is expelled, and in consequence it will naturally lose weight. The amount of this loss, that is, the quantity of contained water, is very different in various plants; ripe seeds dried in the air contain from 12 to 15 per cent. of water, herbaceous plants 60 to 80 per cent., and many water-plants and Fungi as much as 95 per cent. of their whole weight.

The residue, which gives off no more water at a heat of 100° Cent., the dry solid, consists of a great variety of chemical compounds; these are partly *organic*, that is to say, combinations of Carbon with other elements, and partly *inorganic*. Those organic substances which occur in the living plant (with the exception of salts of oxalic acid) all contain Hydrogen. Some of them, such as many oils, consist of these two elements only (Carbon and Hydrogen), but by far the greater number, including Cellulose, Starch, and Sugar, as well as the vegetable acids, and certain oils, contain Oxygen also. The albuminous substances consist of Carbon, Hydrogen, Oxygen, Nitrogen, and Sulphur; in other bodies which contain Nitrogen, as Asparagin and many alkaloids, there is no Sulphur; from certain other alkaloids, for instance Nicotin, Oxygen is also absent.

The organic compounds can for the most part be resolved into volatile products—chiefly carbonic acid, water, and ammonia—by exposure to great heat with free access of air, that is, by combustion. The inorganic residue is a white, or, if the combustion is imperfect, a grey powder, the *ash*.

As the result of chemical processes attending the combustion, the sulphur previously contained in the organic compound appears as sulphates in the ash, and the carbonic acid formed during combustion combines with some of the inorganic substances. These, therefore, must not be included in an accurate estimate of the constituents of the ash.

The ash usually constitutes but a small percentage of the whole dry solid of the plant. The following analyses of various portions of plants will give an idea of its amount and composition:—

1000 PARTS OF DRY SOLID MATTER CONTAIN:

	Ash.	Potash.	Soda.	Lime.	Magnesia.	Ferric Oxide.	Phosphoric Acid.	Sulphuric Acid.	Silica.	Chlorine.
Clover, in bloom	68·3	21·96	1·39	24·06	7·44	0·72	6·74	2·06	1·62	2·66
Wheat, grain	19·7	6·14	0·44	0·66	2·36	0·26	9·26	0·07	0·42	0·04
Wheat, straw	53·7	7·33	0·74	3·09	1·33	0·33	2·58	1·32	36·25	0·90
Potato tubers	37·7	22·76	0·99	0·97	1·77	0·45	6·53	2·45	0·80	1·17
Apples	14·4	5·14	3·76	0·59	1·26	0·20	1·96	0·88	0·62	—
Peas (the seed)	27·3	11·41	0·26	1·36	2·17	0·16	9·95	0·95	0·24	0·42

These constituents of the ash do not form a merely accidental mixture; it has been proved by experiment that certain inorganic matters are absolutely necessary to the life of the plant. Those elements which the plant requires for its nutrition, and which must therefore be regarded as part of its food, are:

I. Those forming the *organic compounds*. Carbon, Hydrogen, Oxygen, Nitrogen, and Sulphur.

II. Those forming the *inorganic compounds*. Phosphorus, Chlorine, Potassium, Calcium, Magnesium, Iron.

Besides these we find in the ash of many plants—though they cannot be regarded as essential to nutrition—the following elements:

Sodium, Lithium, Manganese, Silicon, Iodine, Bromine, and in rare cases, also Aluminium, Copper, Zinc, Cobalt, Nickel, Strontium, and Barium.

Fluorine must also exist in vegetables, for it is found in a perceptible quantity in the dentine of animals which feed directly or indirectly on vegetables.

§ 33. **The Absorption of Carbon.** The source from which all plants containing chlorophyll derive their carbon is simply and solely the carbonic acid of the atmosphere (or in the case of submerged plants, that which is held in solution by the water), which is decomposed under the influence of light by the cells which contain chlorophyll. If a water-plant (*e.g.*, a leaf of *Potamogeton natans*, or a portion of the stem of *Elodea canadensis*) be placed in water which holds carbonic acid in solution, and be exposed to sunshine, it will be seen that from the cut surface of the leaf or stem bubbles of gas are given off at regular intervals (Fig. 66). These consist of oxygen. The carbonic acid is in fact decomposed in the chlorophyll-corpuscles in such a way that part of its oxygen is restored to the atmosphere, whilst the residue combines with the elements of water to form organic compounds, which therefore contain carbon, hydrogen, and oxygen; the last, however, in smaller proportion than does carbonic acid (CO_2). Since almost all the constituents of the food of plants (and not carbonic acid only) are compounds which are rich in oxygen, containing, in fact, for the most part the maximum proportion of that element, and since the products formed within the plant itself are all very poor in oxygen, —some of them being wholly destitute of it,—it is a necessary inference that in the course of nutrition considerable quantities of oxygen must be evolved.

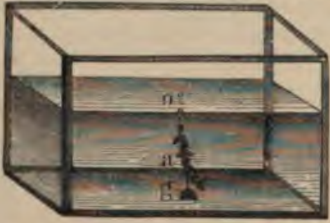


FIG. 66.—Evolution of oxygen from a water-plant (*Elodea Canadensis*): *a* the cut stem; *g* a weight that keeps the stem in its place; *o* the gas-bubbles rising from the cut surface.

The first organic compound which can be detected as a product of this process is in most plants *Starch* ($C_6H_{10}O_5$), which makes its appearance in the chlorophyll-corpuscles in the form of minute granules; sometimes grape-sugar is formed instead. A certain temperature and the co-operation of light are both indispensable to this process; in the dark no oxygen will be eliminated, and the formation of starch-grains in the chlorophyll-corpuscles will also be no longer observable. Of the different rays which compose the solar spectrum, the least refrangible, and particularly the yellow rays, have the most effect in promoting this process. The organs which are adapted for the performance of this function are those which are rich in chlorophyll, particularly the foliage leaves.

No carbon is assimilated by green plants in any other way; excepting this particular process, there is no instance in all nature of the conversion of carbonic acid into organic compounds which contain a smaller proportion of oxygen; hence all carbon, even that contained in the organic compounds of the animal body, is derived from the carbonic acid decomposed in the chlorophyll-corpuscles.

A number of plants which are not furnished with chlorophyll—for instance, all Fungi and a few of the higher plants, as the Dodder (Cuscuta), Orobanche, and Monotropa—are unable, in consequence of its absence, to decompose carbonic acid; hence they are compelled to derive their organic compounds directly from other living plants, or from the decomposing remains of other organisms (humus): in the former case they are said to be *parasites* (*e.g.*, Cuscuta, Orobanche); in the latter they are called *saprophytes* (*e.g.*, Mushrooms, Neottia, Monotropa, etc.).

§ 34. **Metabolism.** The substance formed in the chlorophyll-corpuscles—that is, starch, in the majority of plants—constitutes the raw material from which all the other organic substances of the whole plant are elaborated. In this process of elaboration, the combined nitrogen and the inorganic substances absorbed from the soil, and the oxygen taken up from the atmosphere, are also concerned. The starch-grains (or their physiological equivalent) are continually being absorbed and removed from the chlorophyll-corpuscles. Under normal vital conditions, when the plant is exposed to the light, the formation of starch is in excess of the immediate consumption, so that starch-grains are always to be found in chlorophyll-corpuscles; but if the plant be placed in the dark, the starch-grains gradually disappear.

Of all the substances which are elaborated in the plant, those are the most important which contribute to form the substance of the cell-walls and of the protoplasm; they are spoken of as *plastic* substances.

The cell-walls consist of cellulose, $C_6H_{10}O_5$. It has been shown that Starch, Sugar, and Inulin, which have a similar chemical constitution, as well as fatty matters, all serve as material for the formation of cellulose, and are thus the plastic substances for the cell-walls.

The protoplasm consists essentially of albuminous substances (proteids), which all contain nitrogen and sulphur; such albuminous substances and other nitrogenous compounds, as asparagin, constitute the plastic materials for the protoplasm and allied structures, such as the chlorophyll-corpuscles.

The plastic substances are not consumed at once in the organs in which they are formed, but they are generally utilized in other parts of the plant and at a later period: hence they are stored up for a time, sometimes for a long time, in considerable quantities in special organs, and are then called *reserve-materials*. The seeds of all plants are organs for the storage of such reserve-materials; they contain, besides the embryo, the nutritive substances which it requires during the first stages of its development. Tubers are also such organs, and thickened roots (Potato and Dahlia tubers, Turnips), as well as the persistent parts of perennial plants, such as the rhizomes of herbaceous plants, certain parts of the tissue of the branches and trunks of trees and shrubs, and in evergreen plants even the leaves themselves.

Potato tubers, for instance, contain, as is well known, a great quantity of starch; when the buds grow out into shoots, and new plants begin to be formed, the starch disappears in proportion as new cell-walls are developed. In the same way the starch of the seeds of cereals, the cane-sugar of the beet-root, the inulin of Dahlia tubers, the fatty oil of the seeds of the Rape, the Pumpkin, the Sunflower, and other plants, is used up in the formation of the cell-walls of the new plant. Certain layers of cells, particularly the cells of the medullary rays of trees, contain, in the winter, a quantity of starch which is absorbed and consumed during the spring when new shoots are developed. Cellulose itself occurs as a reserve-material in the seeds of the Date and other Palms; the remarkably thickened walls of endosperm-cells are absorbed during germination, and subserve the growth of the seedling. The proteid-grains (aleurone) described in § 15 are the albuminous reserve-materials of the seed.

If seeds are made to germinate, or if shoots grow out from other deposits of reserve-material, as potatoes and the like, in the dark, no fresh formation of plastic substances can take place, so that the whole of the newly-formed cells are developed at the expense of the reserve-materials; thus the degree of development reached by plants grown in the dark depends on the supply of reserve-materials, which varies in different plants. For instance, if the tiny seed of the Tobacco germinates in the dark, only a minute seedling is developed, while a potato tuber or a beet-root can nourish large plants.

The plastic substances which are stored up as reserve-material undergo a series of changes before they attain their final form, which may be cellulose, or the proteid of protoplasm. The plastic materials for the cell-walls, whether they are deposited as starch, cane-sugar, inulin, fatty oils, or cellulose, are always in part changed into grape-sugar, which is conveyed in solution through the parenchymatous cells by diffusion to the spot where it is to be utilized,—that is, to the place where the new cells are being formed. Very frequently a temporary deposition of it in the form of starch occurs in the conducting tissues, more particularly in the bundle-sheaths.

The intermediate forms assumed by the albuminous reserve-substances are but little known. These substances appear generally to travel slowly through the thin-walled elongated cells of the phloëm, but in some plants asparagin appears as an intermediate form, which travels through the parenchymatous tissue.

The starch of the chlorophyll-corpuscles is conducted, in the same way as the starch of the reservoirs of nutriment, to the spot where it is to be utilized, partly in promoting the growth of the new organs, and partly in being stored up in one of the depositories in the form of one of the above-mentioned substances.

A great number of compounds of carbon occur in plants, which stand in no direct relation to the development of new cells; they are the *by-products* of metabolism, which are formed partly as an inevitable result of the various changes effected in the different plastic substances, and partly also in connection with the performance of functions which are at present in great measure unknown. Among these by-products are Tannin, Colouring matters, Acids, Alkaloids, Volatile Oils, etc. They also are formed from the reserve-materials, which are therefore never entirely consumed in the construction of new organs.

Finally, the *products of degradation* are the last terms of the series of changes expressed by the word metabolism. They can undergo no further modification in the organism, and they have been formed from its organized constituents. To these belong most kinds of gum. In Gum Tragacanth, which is excreted by many species of Astragalus, the organization of the cell-walls is plainly perceptible; they have become capable of swelling-up enormously;

Cherry Gum is formed in the same way from cell-walls which have become difluent, but it is not soluble in water. Gum Arabic, which is formed by several kinds of Acacia, consists of cell-walls which have been so greatly changed as to be absolutely soluble in water.

§ 35. **The Source and Significance of the other Constituents of the Food.** All the nutriment of plants, with the exception of carbonic acid, is derived from the soil.

The *Hydrogen* of the organic compounds is obtained by the decomposition of the water which permeates every part of the plant, and is constantly being absorbed from the earth.

Nitrogen, which is an essential constituent of albuminous substances, is never assimilated in a free form; although it is present in large quantities in the atmosphere, a plant perishes if the soil in which it grows contains no compounds of nitrogen. Nitrates and compounds of ammonia are widely distributed, and it is in this form that nitrogen is taken up by the plant.

The small group of *carnivorous* plants, such as Drosera and Utricularia, have a special means of obtaining nitrogenous food; by their leaves they capture small insects, etc., and absorb compounds of nitrogen from them.

Sulphur, which is a constituent of albuminous and a few other substances occurring in plants, such as oil of Mustard, is derived from the sulphates of the soil. Probably the formation of crystals of oxalate of lime is connected with the decomposition of the absorbed sulphates: the oxalic acid of the plant combines with lime to form oxalate of lime, liberating sulphuric acid which then undergoes further decomposition.

Phosphorus is a constituent of the phosphoric acid which is always found associated with the albuminous substances, and which seems to stand in some close relation to them; phosphates constitute a large proportion of the ash of seeds.

Iron, though it is met with in very small quantities, is absolutely necessary for the formation of chlorophyll, and therefore also for the formation of starch. The leaves produced by plants which are not supplied with iron during their growth are white so soon as their own store of iron is exhausted; these leaves, which are said to be *chlorotic*, become green in consequence of the formation of chlorophyll, if the soil be supplied with iron, or even if their surface only is washed with a very weak solution of iron.

Potassium is found in the form of salts combined with various organic acids, as tartaric acid, racemic acid, and oxalic acid. Unless the soil contains potassium, no formation of starch can take place in the chlorophyll-corpuscles; further, the potassium salts must bear some relation to the plastic materials of the cell-walls, since they are found for the most part in those portions of plants which are rich in starch, sugar, or similar substances, as in potatoes, beet-roots, and grapes.

Calcium and *Magnesium* have been shown to be necessary to the normal development of plants, but nothing beyond this is accurately known as to their function. They occur as salts of lime and magnesia in combination with both organic and inorganic acids.

As regards *Chlorine*, it has been experimentally proved so far to be indispensable in the case of one plant only, the Buckwheat (*Polygonum Fagopyrum*).

It has been discovered by experimental cultures, that a plant can be perfectly nourished if it is supplied with all those elementary substances which have been enumerated as essential. This might be done, for instance, by supplying it with either of the two following groups of chemical compounds:

1.	2.
Calcic nitrate	Calcic nitrate
Potassic nitrate	Ammonic nitrate
Potassic superphosphate	Potassic sulphate
Magnesic sulphate	Magnesic phosphate
Ferrous phosphate	Ferrous chloride.
Sodic chloride.	

In these two mixtures, as well as in others of the same acids and bases which might be formulated, all the essential elements are included in forms suitable for absorption.

§ 36. **The non-essential Constituents of the Ash.** *Silica*, a compound of silicon and oxygen, is distinguished from the previously-mentioned constituents of the ash, not only in that it occurs sometimes in greater and sometimes in smaller quantities, but more particularly in that the amount of it present in any organ increases with the age of the organ. Hence it may be inferred that it can hardly stand in any direct relation to the chemical processes of nutrition. Moreover, plants which are usually rich in silica can be brought to an apparently normal development under conditions which render the absorption of silica impossible.

Iodine and *Bromine* are found in many marine plants, especially in Algæ, and are prepared from them; it is not known if they are of any value in the economy of the plant.

Sodium, being universally distributed, is found in plants.

Lithium occurs in the ash of several plants, particularly in Tobacco.

Zinc, *Copper*, and other metals, though they are not commonly present in the ash of plants, are nevertheless taken up by plants from soils which are rich in them; from this it appears that plants may absorb substances which are not necessary for their nutrition.

§ 37. The Absorption of the Constituents of the Food from the Soil. With the exception of floating water-plants, which derive the whole of their nutriment, even their carbonic acid, from the water which surrounds them (*e.g.*, Utricularia), most plants grow in damp, or in dry, porous soil, from which they absorb all their nourishment except carbonic acid. The organs by which this is effected are the roots, or, in rootless plants, hairs, shoots, or branches of the thallus, which take the place of roots. The epidermal cells and (Fig. 67 *h*) root-hairs come into close contact with the minute particles of the soil, and with the water which adheres to these particles. Some nutrient substances are held in solution in the water of the soil, and pass directly into the root-cells by diffusion: others are decomposed by the acid sap which is contained in the cells and which saturates even their cell-walls, and they then pass into the plant in the form of salts of organic acids. If a plant is allowed to grow over a plate of polished marble, the calcic carbonate is decomposed at those parts of the plate which are in direct contact with the roots, and a complete outline of the whole root-system is produced upon the marble. Thus although these nutritious substances are so firmly retained by the soil that they cannot be dissolved out of it by water, they are nevertheless absorbed by the plant. The plant is enabled to take up these as well as other substances which occur in a solid form, in consequence of the very intimate connection of the root-hairs with the particles of the soil. If a strongly-growing plant be pulled up out of the ground, those parts

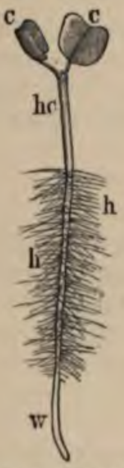


FIG. 67. — Root-hairs (*h*) on the primary root (*w*) of a germinating plant of Buckwheat grown in water (*Polygonum Fagopyrum*); *h c* hypocotyledonary portion; *c* cotyledons.

of the root which are provided with hairs—neither the apex nor the oldest portion—will be seen to be closely covered with earthy particles which cannot be removed without tearing the hairs.

It has been found that the ash of plants which grow close together in the same soil or in the same water, may have a composition which is different in different cases, and which is different also from that of the soil; hence it has been inferred that plants have a certain power of selection, that they can absorb certain matters and reject others. This phenomenon can, however, be more simply explained by the known laws of diffusion. A substance which is held in solution by the medium which surrounds the plant will continue to diffuse into the cells of the roots until equilibrium is set up between the two fluids separated by the membrane, and this is equally true of those substances which are at once absorbed by the plant as of those which are brought into solution by it before absorption. If the substance is not consumed in the plant and consequently remains unaltered, the state of equilibrium once set up is permanent, and no more of that substance will be absorbed; but if it is consumed in the plant, undergoing chemical change in the process, it ceases to exist in the plant in its original form, and fresh supplies will be constantly absorbed. Since these chemical changes differ in different plants, it is possible to account in this way for the variety in the composition of the ash of plants which have grown side by side.

The fact that certain constituents of the ash are indispensable to the life of plants is of the greatest importance in agriculture. All the constituents of the ash, as well as the nitrogenous compounds, are removed every year in considerable quantities from the soil at the time of harvest. Those which exist in the soil in relatively small quantity, such as phosphoric acid and compounds of potassium and of nitrogen, must be restored to it: this restitution is the object of manuring.

§ 38. **Oxygen; the Respiration of Plants.** In the process of nutrition a large quantity of compounds of oxygen is being constantly introduced into the plant; and, since the assimilated substances which are formed from the compounds are very poor in oxygen, it follows that during assimilation a considerable portion of the oxygen absorbed in a combined form must be liberated and evolved by the plant. In contradistinction to this process—which is effected exclusively in the cells containing chlorophyll and under the influence of light—all living parts of a plant, at all times, take up oxygen from the atmosphere and give off carbonic acid. This process is *Respiration*, which must be clearly understood to be quite distinct from the process of the formation of starch. The fact that green plants decompose carbonic acid in the one process, and form carbonic acid in the other, and continue at the same time to increase in weight and to accumulate carbon-compounds, can be simply explained thus—that the respiration of these plants is usually feeble, while the formation of starch under favourable circumstances is extremely active. If these plants be kept in the dark, they cannot form starch, and they must necessarily lose weight and at length perish. The more vigorous growth is, the more vigorous is respiration. It is absolutely indispensable to the life of the plant; in an atmosphere deprived of oxygen all the vital processes are suspended, the movements of the protoplasm cease, the irritability of sensitive leaves disappears, as in Mimosa, Oxalis (see § 50), and at last the death of the plant takes place. By respiration force is obtained, and new chemical processes are initiated.

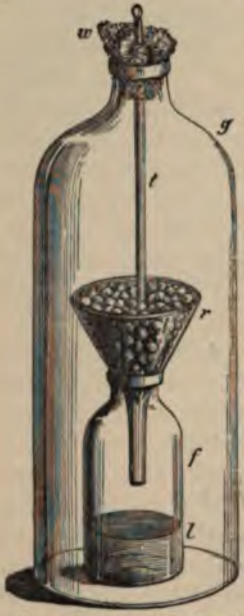


FIG. 68.—Apparatus for detecting the rise of temperature in small opening flowers or germinating seeds. The seeds are heaped as closely as possible in the funnel *r* which is inserted into the mouth of a bottle containing a solution of caustic potash. This absorbs the carbonic acid produced by respiration. The whole is enclosed in a glass vessel, and a delicate thermometer is inserted through the cotton wool which closes the mouth. The bulb of the thermometer is plunged in among the seeds. The temperature in this apparatus will be higher than in another arranged in the same way for comparison, and in which the portions of the plant are replaced by scraps of paper, etc.

As in all other processes of oxidation, heat is set free by respiration in plants; but as other conditions lead to rapid cooling, no rise of the temperature is usually observable as the result. A rise of temperature is perceptible in special cases only, in which respiration is very active, and in which the conditions are unfavourable to rapid cooling, as in the germination of seeds which lie very closely together, *e.g.*, the seeds of barley in the process of malting; this consists in causing the barley to germinate by moisture and warmth, so that the starch which the seeds contain may be converted into sugar; during this process a perceptible rise of temperature occurs.

During the blossoming of many infloresences, as, for instance, of Aroids, a rise of temperature amounting to 4°, 5°, or even 10° above that of the air has been observed. By means of suitable apparatus (see Fig. 68) a similar rise of temperature may be detected in other plants, even with quite small flowers, as well as during the germination of seeds.

Finally, in the few cases in which *Phosphorescence* has been proved to occur in living plants, as in various Fungi, *e.g.*, *Agaricus olearius;* this phenomenon is intimately connected with the taking up of oxygen; the Fungus is luminous only so long as it lives and is surrounded by an atmosphere containing oxygen. The old statements as to the phosphorescence of certain flowers have not been confirmed.

CHAPTER II.

THE MOVEMENT OF WATER AND OF GASES IN PLANTS.

§ 39. **The Slow Movement of Water in the Processes of Growth and of Nutrition.** A potato-tuber, even if kept quite dry, will sprout under the influence of a sufficiently high temperature, and in proportion to the growth of the shoots the tuber will become flaccid and wither, beginning at the more remote parts, in consequence of loss of water. This water is not only of use in that it dissolves nutrient substances and thus renders possible their transport to the apex of the growing shoot, but it is itself of use in the process of growth; for not only are solid particles of cellulose deposited in the growing cell-walls, but also a certain quantity of water; and moreover, the vacuole of the growing cell containing cell-sap also increases in size. The water which is indispensable for these purposes is gradually absorbed from the more remote portions of the tuber. As a consequence, if the tuber be kept dry, it will gradually become flaccid and withered; but if it lies in damp earth, it takes up water from the soil, and thus water is conveyed with the nutrient materials to the growing parts. Water is similarly conveyed to the developing buds of trees, to the growing-points of seedlings, and generally to all growing parts of plants, from the nearer parts in the first instance, then from the more distant, and finally from the external medium. This water travels slowly from cell to cell; as the equilibrium between the individual cells is destroyed by the consumption of water in the growing cells, the water from the more distant portions of the tissue is absorbed to restore it.

§ 40. **Transpiration.** Every part of a plant which is exposed to the air and which is not covered by a layer of cork or of cuticle, is constantly losing water by evaporation into the atmosphere. If a stem bearing leaves be placed under a bell-jar at a sufficiently high temperature, the glass will be soon covered with drops of water, in consequence of the condensation of the vapour given off by the plant. Transpiration is naturally the more energetic the higher the temperature and the drier the surrounding air. This loss of water is compensated by the absorption of water from the soil by the roots and its conveyance to the transpiring organs of the plant. On particularly hot days it sometimes happens that the leaves of trees and herbaceous plants lose more water than their roots can replace, and they droop and wither. This drooping occurs conspicuously in parts of plants which have been cut off. The transpiration varies in quantity according to the special organization of the plant and of its separate parts. The stems of most woody plants and trees are almost entirely prevented from transpiring by thick layers of cork, and transpiration is small in such stems and leaves as are covered with a thick cuticle, as the leaves of Agave, the stems of Cactus, and similar plants; these when cut off wither slowly, and they can thrive in a very dry soil. Tender leaves, on the contrary, in which the cuticle is but slightly developed, as those of Tobacco and Pumpkin, wither as soon as they are removed from the plant, or if the soil becomes too dry.

The stomata affect the transpiration of the plant inasmuch as they are the external openings of the intercellular spaces into which transpiration takes place from the neighbouring cells, and from which the watery vapour escapes into the external air.

§ 41. **The Movement of Water through the Wood.** The water given off by transpiration is conveyed to the transpiring organs from the roots through the wood (xylem). If a ring of cortex be cut away from a tree so that all conduction through the cortex is interrupted, the leaves will not wither so long as the wood is uninjured; water is still conveyed through it to them. If a cut branch be placed in a solution of some colouring-matter such as Anilin, the colouring-matter rises through the wood with the water. That the lignified cells of the xylem serve for the conduction of water is also confirmed by the fact that submerged water-plants which can have no transpiration have no lignified elements in their xylem. In the summer, at the very time when transpiration is most active, the wood-cells contain air; hence the water must travel, not through the cavities of the cells, but in the cell-walls. The cut stems of many plants which are actively transpiring wither very rapidly, and when placed in water take it up only very slowly; this arises from the circumstance that section in air diminishes the conducting capacity of the cut surface: if a portion be cut off from such a stem under water, water is immediately conveyed upward, and the upper portion recovers its turgidity. If water be forced into the stem, the same effect is produced.

The water which rises through the wood-cells to supply the place of that which is lost by transpiration, is taken up by the roots; hence the compensation depends on their activity; if their activity be in any way impaired—for instance, if the soil be too much cooled—absorption is diminished and the plant withers: again, a plant when newly transplanted droops for a time, because the roots are incapable of taking up the requisite amount of water, until a new growth of hairs enables them to become closely attached to the particles of the soil.

Leaves and stems are not capable of absorbing watery vapour from a moist atmosphere, or water when poured over them, to any considerable extent. It is, however, very evident that drooping plants recover their turgidity when they are wetted by dew or rain, or if the air be moist. This is the result partly of an increased supply of water derived from the moistened earth, and partly of a diminished transpiration in consequence of the dampness of the atmosphere.

§ 42. **The Root-pressure.** It is an old observation that Vines when pruned bleed, as it is called, in the spring—that is, that water escapes from the cut surfaces; closer investigation has shown that this water exudes from the openings of the large vessels. A similar bleeding may be observed in several trees, as the Birch and Maple, as well as in all woody shrubs which are growing vigorously and which are provided with a well-developed root-system. If the stem of a Sunflower or of a Tobacco plant be cut off a few centimetres above the ground, and if evaporation from the cut surface be prevented, an out-flow of sap will begin after a time, which may continue for several days. This water is absorbed from the soil and forced up into the plant by the roots often with a force capable of supporting a column of mercury of considerable height.

This root-pressure sometimes gives rise to the exudation of drops of water from different parts of plants, for instance, from the tips of the leaves of many Aroids, and from the teeth of the leaves of *Alchemilla vulgaris;* in the latter instance it may be observed on almost any summer morning, and it is usually mistaken for dew. In a dry atmosphere the formation of drops is prevented because the water forced up from the roots is at once evaporated.

In herbaceous plants the water forced up from the roots contains only a few salts in solution; in the Vine and some trees it usually holds various organic substances, and particularly sugar, in solution.

This movement of water, effected by the root-pressure, is particularly conspicuous in the spring, and generally at the period of most vigorous growth. In plants which have been transpiring vigorously no water exudes from the cut surface in connection with the root when the stem is cut through, until after a certain lapse of time, when the roots have taken up a fresh supply of water. This proves, in the first place, that there is no root-pressure in plants which are actively transpiring, and consequently that the root-pressure does not supply the water lost by transpiration.

A brief consideration of the phenomena which have been described will show that there are three distinct modes in which water moves in the living plant; of these, two are effected by a sort of suction proceeding from the spot where the water is being used, namely: (*a*) the slow movement of the water in the processes of growth, and (*b*) the passage of water through the wood to compensate for the loss by transpiration. The third motion (*c*) is caused by pressure from the roots upwards, independently of any consumption. It must, however, be assumed that absorption is constantly going on at the surface of the roots, and that the internal tissues are so arranged that the water which is absorbed can be forced upwards.

In winter, the wood-cells contain water together with larger or smaller bubbles of air; hence it happens that if a hole be bored into a tree in winter, when the temperature is rising, the water is driven out by the sudden expansion of these air bubbles; if, on the other hand, the temperature is falling, their contraction causes an absorption of water.

§ 43. **The Movement of Gases in Plants.** We have seen that every living vegetable cell takes up oxygen, and that the cells which contain chlorophyll consume carbonic acid. Now these gases, in order to reach the interior of the cells, must penetrate the cell-walls, and this is effected by diffusion; they are dissolved by the water which saturates the cell-walls, and are conveyed by it to the point where they are to be consumed. In like manner the cells lose by diffusion the gases evolved within them; oxygen as a product of the decomposition of carbonic acid, carbonic acid as a product of respiration.

Not only do gases thus circulate by diffusion, but they also move freely in the air-passages which usually occur in the tissues of plants, such as the intercellular spaces, the vessels (at any rate in summer), and the cavities formed by rupture, as in the stems of Grasses, Umbelliferæ, etc. These all communicate with each other and, in terrestrial plants, with the outer air by means of the stomata. If air be forced into a leaf which has a large number of stomata—for instance, by placing the blade of the leaf in the mouth and closing the lips tightly round the petiole—bubbles of air will be seen to escape from the cut surface of the petiole, if it be placed in water, which come out of the openings of the vessels. The converse of this experiment is not equally successful, because the stomata of the leaf when immersed become closed by water held by capillary attraction.

A constant interchange is always going on by diffusion between the air contained in these spaces and the contents of the cells; the composition of the air is thus continually changing, and currents are set up between it and the outer air. This movement of the air in the internal cavities is promoted by the swaying of the plant under the influence of the wind, as well as by variations of temperature.

Submerged water-plants have very large cavities filled with air, which do not communicate with the atmosphere by stomata; an interchange of gases cannot take place directly between the individual cells and the atmosphere, but it takes place partly between the cells and the surrounding water which holds gases in solution, and partly between them and the air contained in the air-chambers. The gases frequently collect in these chambers in such volumes as to set up a pressure sufficiently great to rupture the surrounding tissues.

CHAPTER III.

GROWTH.

§ 44. **The Process of Growth.** Plants and their organs grow, that is, they increase in bulk and at the same time alter in form; these changes, which are permanent, are brought about by internal processes. A portion of a plant which has become withered increases in volume when placed in water, but this is not growth; for if water be again removed from it, it returns to its former dimensions, and evidently no permanent change had been effected. But the case is quite different with a ripe seed; if it be supplied with water it will germinate, that is, the embryo contained within it will begin to grow, and will escape from it. In this case permanent changes have taken place, and consequently no removal of water will restore the seed to its former condition.

The most important of the internal processes which directly cause these permanent changes is the intercalation of new particles of solid matter as well as of water in the growing cell-walls, by the activity of the protoplasm.

The presence of plastic material is an indispensable condition of growth, but this does not necessarily imply that the nutrition of a growing plant depends upon the simultaneous absorption of nutritious matters from without; on the contrary, the young growing parts of a plant are usually supplied with plastic material from the older parts which have ceased to grow. These older parts may be reservoirs of nutriment, as the tubers of the Potato, or they may be factories of nutriment, as the leaves in annual plants, *e.g.*, the Tobacco; here the full-grown leaves form starch, and the stem and young leaves grow at the expense of the plastic material thus elaborated.

A second indispensable condition is the presence of water. This is required not merely to enter into the formation of the cell-wall and to convey the plastic materials, but to maintain the cells in a state of *Turgidity*, without which growth is impossible. The turgid condition is brought about by the endosmotic absorption of so much water that the elastic cell-wall is rendered tense by the hydrostatic pressure. As a consequence, the solid particles composing it are forced as far as possible apart from each other, the intermediate fluid areas are enlarged, and the intercalation of additional solid particles is rendered possible.

§ 45. **The Growth in Length of Stems, Leaves, and Roots.** Growth is brought about by internal causes; there are parts of plants which, when they have attained a certain size and shape, are incapable of any further growth; others, as the nodes of Grass-stems, may begin to grow again under certain circumstances. Growth is influenced by external conditions, such as moisture, warmth, light, and gravitation. It will be advantageous to study, in the first place, the course of growth when it is not affected by these external influences. Of this, the roots offer the simplest examples. In a growing root three regions may be distinguished:

I. *The growing-point*, where new cells are being formed in great numbers from the primary tissue (*meristem*) by repeated division, but where no considerable increase of their size takes place.

II. *The elongating portion*, that is to say, the part in which growth, chiefly in length, is taking place; in this region the cells are increasing considerably in size, and cell-division occurs only in relatively small proportion.

III. *The fully-developed portion*, in which various modifications of the cells take place, but no further growth.

Stems which attain a considerable length grow much in the same way as roots; in them also, as in roots, a mass of cells is formed by division at the apex, which undergo elongation at a lower level, and at a still lower cease to grow altogether. When, however, a stem possesses clearly defined internodes (see § 2), a further complication takes place, for within each internode similar stages of growth are exhibited; moreover, the nodes cease to lengthen at an early stage, whereas the internodes continue to grow for some time.

Most leaves consist at first of primary tissue, the cells of which are undergoing division; they attain their full development in different ways, but in all cases no part of the primary tissue remains as a growing-point so as to provide for continued growth. These three stages, the preparatory, the growing, and the final, are successively gone through by each individual cell. So soon as it has been formed from the primary tissue, it begins to elongate in order to attain its definitive length. It grows at first slowly, but the rapidity of its growth gradually increases until at a certain period the maximum is reached; it then gradually diminishes, and the cell finally ceases to grow. This periodicity of growth is coincident in all the cells which lie at the same level, so that in a growing part of a plant there is a certain zone where growth is most vigorous, and on each side of it the rapidity diminishes.

Every part of a plant exhibits a *grand period* in the rapidity of its growth: it begins to grow slowly; at a certain time it grows with a maximum rapidity; after this the rapidity of growth gradually diminishes until the whole organ is fully developed. Apart from the increase and diminution in the rapidity of growth, the time must be taken into account during which an organ can continue to grow, as well as its capability of attaining a certain length. For instance, it is easy to observe that the lower internodes of most stems remain short; that those above them are longer; that those of a certain part of the stem are the longest; and that the upper ones again are short. In the same way the size of the leaves attached to these various parts of the stem increases from below to about the middle, and then diminishes.

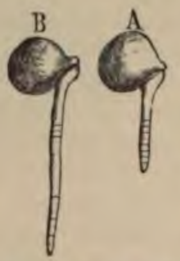


FIG. 69. — The growing primary root of the Pea in two stages. *A* The root is marked by lines at equal distances. In *B* the differences in rapidity of growth are perceptible: the uppermost lines have not been separated; the root has ceased to grow here. The lowest likewise are still close together. At the growing-point here elongation has not yet begun. In the intermediate zone the elongation has been very great.

§ 46. The Properties of Growing Parts.

If a stem which has ceased to grow in its lower portion, but which is still growing at its upper part, be strongly bent, on being released the fully-grown portion will resume its original position, whereas the growing part will retain the curvature given to it. From this it appears that the growing parts of a plant are highly flexible but imperfectly elastic. This explains the following experiment: if a sharp blow be given to the lower rigid part of a growing shoot of the Meadow Thistle (*Carduus pratensis*), for instance, or to a strong shoot of the Raspberry, the upper growing portion becomes sharply curved; this curvature persists after the shoot has come to rest, in such away that the apex is inclined towards the side from which the blow came.

If a growing internode be divided longitudinally down the middle, the two halves separate widely; this is due to the fact that the pith tends to elongate more than the other tissues, and is prevented from doing so by them; as far as their extensibility allows, these tissues are stretched, and in this way tensions are set up. If the various tissues be completely separated from each other with a sharp knife, each will acquire a different length; the pith becomes longer than the internode originally was; the outer tissues retain the same length or shorten, in which case the epidermis contracts the most.

§ 47. **The Influence of External Conditions on Growth in Length.** The most important of these is *Moisture.* If the cells of an organ be not tensely filled with water (turgid), that organ will not grow at all.

With regard to the dependence of growth upon *Temperature*, it is to be observed that the more favourable the temperature the more rapid is the growth. In general, the account given in § 51 of the relations existing between temperature and the vital functions of the plant holds good with reference to growth.

Light exercises a retarding influence on growth. It is an old observation that those stems which develop in the dark—for instance, potato-shoots in a cellar—grow to a much greater length, that is, they have much longer internodes, than those which grow normally in the light. Plants which have grown in darkness, and which are therefore abnormal in form, are said to be *etiolated.* Their internodes are very long, their leaves are not green but yellow, and usually much smaller than the normal leaves; this is due to a morbid condition induced by the absence of light, for the presence of light is an essential condition for the performance of certain important functions. The retarding action of light on growth also causes the curvature of stems which have been illuminated on one side only during their growth, as, for instance, in the case of plants grown in a window. The feebler the light to which it is exposed, the longer will an internode become; so, when the light comes from one side only, the side of the stem most remote from the source of light is more feebly illuminated, and consequently grows longer than that which is nearer to the source of light; as a necessary consequence, the stem will curve in such a way that the concavity is directed towards the source of light. This property, which is exhibited by most organs, is known as *positive heliotropism.* Petioles are always positively heliotropic, and when illuminated from one side only, they curve in such a manner that the upper surface of the lamina is always turned towards the light; in this process, however, other properties also take part. In contrast to positive heliotropism, a *negative heliotropism* is exhibited by a few vegetable organs—*e.g.*, the older internodes of the stem of Ivy and many roots—which curve away from the source of light in consequence of the more vigorous growth of the more strongly illuminated side. The nature of heliotropism is not yet perfectly known.

Gravitation also influences growth: it is manifest that most stems and trees grow straight up from the earth's surface at all parts of the globe, in the direction of a prolonged radius of the sphere; in the same way roots, and particularly primary roots, grow straight downwards, and branches and leaves grow outwards at certain angles. If a growing stem be placed in a horizontal position, the growing portion curves (Fig. 70 *s*) so that its upper surface becomes concave, its lower convex, and it is said to be *negatively geotropic;* consequently the free end is directed upwards and continues to grow in a vertical direction. In the same way the growing end of a root laid horizontally curves downwards (Fig. 70 *w*); it is therefore *positively geotropic.* If by means of appropriate apparatus germinating seeds be caused to rotate round a centre in a vertical plane (Knight's machine), the roots obey the centrifugal force, as they do gravitation under ordinary circumstances, and grow away from the centre in the radial direction; while the stems, on the contrary, grow towards the centre, in opposition to the centrifugal force. That the force which determines the direction of growth of parts of plants under ordinary circumstances is in fact gravitation, is not only indicated by the coincidence of the direction of the growth of the axes of plants with the radius of the earth at all points of its surface, but it can also be proved by direct experiment. Thus if plants are withdrawn from the influence of gravitation by being made to rotate slowly, so that at every moment the force of gravitation is acting upon them in a new direction, the effects produced by the action of gravitation in successive periods of time neutralise each other, the plants—roots and stems alike—will grow in indeterminate directions.

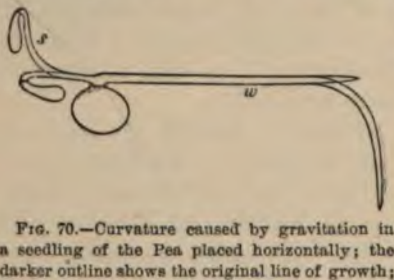


FIG. 70.—Curvature caused by gravitation in a seedling of the Pea placed horizontally; the darker outline shows the original line of growth; *s* stem which has curved upwards (negative geotropism); *w* the root which has curved downwards (positive geotropism).

§ 48. **Bilateral Structure of Plants.** Many plants are so organized that their different surfaces do not grow equally; thus in young leaves the under surface at first grows more vigorously than the upper (*hyponasty*), so that they lie folded over the end of the stem, and their subsequent unfolding is occasioned by a more vigorous growth of the upper surface (*epinasty*). This unequal growth depends wholly on internal causes and not on external influences. Usually these phenomena are exhibited by two surfaces, and such portions of a plant are said to be *bilateral*. But there are also parts of plants which become bilateral under the action of external influences; organs, that is, the surfaces of which grow unequally because they are not equally sensitive to the action of these external influences.

The co-operation of the internal causes, that is, the tendency towards a bilateral structure, with external influences such as light and gravitation, gives rise to the varieties of position which the parts of plants assume in nature, particularly the horizontal or oblique direction of stems, branches, leaves, lateral roots, and so on.

It is by unequal growth that those movements are produced which are expressed by the word *Nutation*. If the movement takes place only from behind forwards, or from right to left, in consequence of the alternately more vigorous growth of the posterior or right side and of the anterior or left side, the nutation is *simple;* but if it occurs in every direction, in consequence of the more vigorous growth of each side in succession, the nutation is said to be *revolving*.

Revolving nutation is very conspicuously exhibited by climbing plants, *e.g.*, the Hop, Bean, Bind-weed, etc. (v. Fig. 15 *B*). So long as the growing end of such a stem does not come into contact with a support, the revolving nutation carries it round in a circle. If in the course of its nutation the anterior surface of the stem comes into contact with a support which is not too thick, the movement of nutation is altered in such a way that the apex of the stem, as it grows, will describe an ascending spiral around the prop as its axis; then the turns of the spiral become steeper and narrower, and cling tightly to the support. Most climbing plants twine to the left, that is to say, the spiral ascends from left to right; only a few, as the Hop, twine to the right.

In climbing stems it is immaterial which surface comes into contact with the support: in this respect they differ from *Tendrils*, of which usually one side, and that the under side, is capable of becoming concave as the result of contact with a support. They curve in consequence of the contact, which acts upon them as a stimulus. As a result of the curvature thus induced, fresh portions of the under surface are brought into contact with the support, and the curvature continues until at last the whole free portion of the tendril is wound round it. The stimulation which is effected by the pressure is propagated through the portion lying between the support and the base of the tendril: this portion then contracts and assumes the form of a cork-screw, thus drawing the stem close up to the support (Fig. 15 *A s*). These curvatures of climbing plants and of twining tendrils are accompanied by *torsion*, that is, by a twisting of the organ round its own axis of growth. Torsion may be produced in various parts of plants, partly by external and partly by internal causes; thus, to give one of numerous instances, horizontal or oblique branches with opposite decussate leaves may be found in which the leaves appear to be arranged in two rows only in consequence of the torsion which the internodes between the pairs of leaves have undergone.

The *alternate opening and closing* of many flowers, such as the Crocus, is likewise an effect of bilateral structure. The lower parts of the petals are still in a growing condition and are highly sensitive to changes of light and of temperature, so that when the temperature is rising and the light increasing, the inner side grows the faster and the flower opens; as the temperature and light diminish, the outer side grows the faster and the flower closes.

§ 49. **Growth in Thickness of Woody Plants.** The processes of growth in the cambium which lead to an increase in size of the wood and of the bast (§ 26) are subject, like those of growth in length, to certain specific internal laws. Thus in the Yew, for instance, very small annual rings are formed; its growth in thickness is very small in comparison with that of Willows, Poplars, Elms, etc. Again, the first annual rings of a young tree are much narrower than those subsequently formed.

Growth in thickness is very obviously dependent upon the quantity and distribution of the nutrient substances formed in the leaves. If a tree loses many of its leaves—as, for instance, when attacked by locusts—the formation of new wood is considerably diminished. The extent of the formation of new wood is not to be measured by the width of the annual ring, but by its cubic content; for it is clear that the same amount of material will give rise to rings, the width of which will vary with the diameter of the wood already in existence. Trees which bear branches and foliage down to the ground naturally have a larger supply of material for the formation of new wood in their lower than in their upper parts, and, as a consequence, the increase in size and the breadth of the rings of wood are greatest below, so that the stem has a distinctly conical form. On the other hand, those trees which bear a crown of leaves at the apex of a long bare stem, even on the assumption that the material is equally distributed and that the growth in thickness is consequently uniform throughout, exhibit wider rings in their upper than in their lower part: the form of their stems is nearly cylindrical.

The pressure exercised by the cortex, rendered tense by the growth in diameter of the wood, has an important influence upon growth in thickness. When this pressure is great, the increase of the wood is less than when the pressure is small. This explains the increase in thickness exhibited by trees when planted out, before any important extension of the foliage can have taken place. The cortex, which had hitherto been in moist air in a confined space, is now exposed to the sun and to dry air; it becomes brittle, and therefore can exert only a slight pressure. The pressure of the cortex has been shown experimentally to be the cause of the formation of spring- and autumn-wood. In consequence of the growth of the wood during the summer the pressure of the cortex becomes considerable, and, as the result, a smaller number of vessels are formed in the wood, and the external layers of wood-cells become flattened. In the spring the pressure diminishes in consequence of the rupture of the cortex, which has become dry during the winter, by the wood which absorbs considerable quantities of water and therefore swells. That most trees cease to grow in thickness about the middle of August is to be attributed to the fact that the pressure of the cortex attains its maximum at that time. With reference to the relation existing between growth in thickness and temperature, it may be mentioned that the cambium of roots which have penetrated to some depth into the soil is active even in winter.

CHAPTER IV.

THE IRRITABILITY OF MATURE ORGANS.

§ 50. The curvatures and movements which have hitherto been considered are only manifested so long as the organs in which they occur continue to grow. But there are many organs, particularly leaves, in different plants, which perform movements even after they are fully grown. The internal processes which produce them are highly complicated; they essentially depend upon an expulsion of water, in consequence of stimulation, from the cells of one side of a particular part of the petiole which is the actual motile organ.

The full-grown leaves of many plants change their position morning and evening, so that a diurnal and a nocturnal position may be readily distinguished. In the nocturnal position the leaves are usually drawn together; in the day position, on the contrary, they are widely expanded. These movements are best known in the case of the Sensitive Plant (*Mimosa pudica*); the pinnæ of the leaves of this plant fold together upwards in the evening, whilst the leaf-stalk bends downwards. The motile organ is the pulvinus which lies at the base of the rachis and of each petiolule. Similar phenomena may be observed in many other leguminous plants, such as the false Acacias and the Bean. The leaflets of the Wood-sorrel (*Oxalis Acetosella*) fall downwards in the evening and expand again in the morning (Fig. 71), and those of other plants behave in a similar manner.

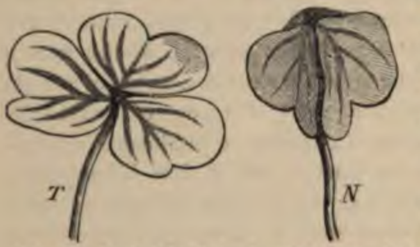


FIG. 71.—Leaf of Oxalis by day (*T*) and by night (*N*). In the latter, each leaflet is folded inwards at right angles along its midrib, and is also bent downwards.

This periodicity is determined by variations in the intensity of light and by changes of temperature. An increase in the intensity of light and a rise of temperature effects the assumption of the diurnal position, and *vice versa*.

These leaves possess also a periodic motion, effected by internal causes, which only becomes evident when the plants are kept for some time in continuous darkness: it is then seen that the leaves are in constant though not very vigorous movement. It appears, therefore, that exposure to light tends to arrest the spontaneous movements, and to cause the leaves to take up the diurnal position. This is known as the *paratonic action* of light. In some few plants these proper periodical movements, due to internal causes, are exhibited under ordinary conditions if only the temperature is high enough. The lateral leaflets of the leaves of *Hedysarum* (Desmodium) *gyrans*, for instance (a papilionaceous plant from the East Indies), constantly perform circular movements which are repeated in from two to five minutes.

Among the leaves which exhibit periodic movements there are a few which possess this peculiarity, that contact with a foreign body causes them to pass from the diurnal to the nocturnal position: this is particularly conspicuous in the leaves of *Mimosa pudica.*

The stamens of many flowers, *e.g.*, of Berberis and Centaurea, are sensitive only to contact; those of Berberis when at rest are extended widely apart; if they are touched on their inner surfaces they bend concavely inwards so as to approach the stigma: those of Centaurea contract when touched, and thereby agitate the whole inflorescence, for they are inserted upon the tubular corolla. The florets are closely aggregated in the capitulum, and, if the hand is lightly passed over it, an active tremulous movement of all the florets occurs.

The hair-like appendages (tentacles) of the leaf of Drosera (Fig. 72 *A*), each of which bears an apical gland, curve inwards when a foreign body touches the glands, or if they are moistened with a nitrogenous fluid, in such a way that the apical glands are collected together at the centre of the leaf. By this means small insects which have been caught by the viscid secretion of the glands are conveyed to the middle of the leaf, and are there brought into contact with as many of the glands as possible; their secretion dissolves all the nitrogenous constituents of the insect, and these are absorbed into the plant. Other carnivorous plants have still more complicated motile mechanisms for the same purpose.

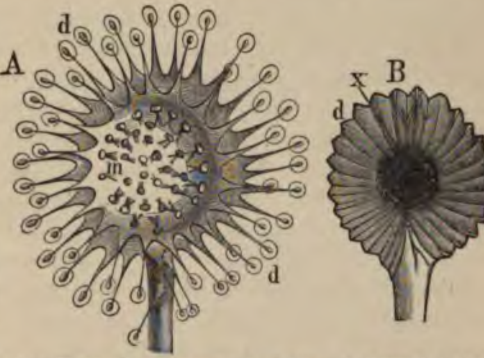


FIG. 72.—Leaf of *Drosera rotundifolia*. *A* Expanded, *d* the tentacles of the edge of the leaf; *m* the stoutly-stalked glands in the middle. *B* All the tentacles have bent towards the middle at the touch of an insect, *x*.

In order that movements of the leaves may take place, the plant must possess a certain degree of irritability. Long-continued exposure to darkness, or to too high or too low a temperature, or the action of chemical or electrical stimuli, induces a condition of rigidity: when this is the case, no stimulus will produce any movement.

CHAPTER V.

THE GENERAL CONDITIONS OF PLANT-LIFE.

§ 51. **Temperature.** As, with a few exceptions, the evolution of heat within the plant itself is extremely slight, its temperature depends almost entirely upon that of the surrounding medium: equilibrium is set up between it and the plant partly by conduction and partly by radiation. Since plants are bad conductors of heat—that is to say, they undergo changes of temperature very slowly—when the changes in the temperature of the air are rapid and extreme, the temperature of a plant is frequently different from that of the air, either higher or lower; but when the changes are slow, as is the case when the surrounding medium is water or earth, the temperature of the plant is very nearly the same as that of the medium. As regards radiation, it is an important cause of changes of the temperature of plants, particularly of leaves. When the sky is clear, these organs become much colder than the surrounding air, particularly at night, in consequence of radiation, and it is on this fact that the formation of dew and hoar-frost depends. A further cause of the cooling of those parts of plants which have a considerable extent of surface exposed to the air, is evaporation, which operates chiefly by day, and tends to reduce the temperature of the leaves below that of the surrounding air.

Every process going on within a plant is connected with a certain range of temperature, that is to say, there is a certain minimum degree and a certain maximum degree of temperature, below or above which the process in question cannot take place. This obtains for growth, for the formation of starch, for the movements of protoplasm, for the activity of the roots, and so forth. Between these limits—the maximum and minimum—there is for every function an *optimum temperature*, different for every plant, at which that function is performed with the greatest activity. Thus, when the temperature is rising to the optimum, at every degree it is more favourable; if it rises beyond the optimum towards the maximum, at every degree it becomes less favourable to the performance of any particular function.

It may be generally assumed that all the vital processes of our indigenous plants begin at a certain number of degrees above freezing-point; that up to 25° or 30° C. they increase in intensity and reach their optimum at about 30°; that their activity diminishes from 30° to 45°, and that they wholly cease at about 50°. In plants of warmer climates the lower limit is considerably higher; thus a Gourd seed will not germinate at a temperature below 13° C.

Death, caused by exposure to too high a temperature, is affected by the presence of water; thus, while dry peas lose their germinating power only after exposure for an hour to a temperature of over 70° C., they are killed at a temperature of 54° if they are saturated with water. Most parts of plants will not bear a higher temperature than about 50° C. in air or 45° C. in water for any length of time.

The freezing of plants, that is, their injury or death by cold, only occurs if the temperature of the plant falls some degrees (in some cases even many degrees) below the freezing-point, and if at the same time the plant is in a condition to become frozen. Many plants are not killed by frost, such as Lichens and many Mosses and Fungi; just those plants which can also bear drying up without suffering any damage. The dry parts of plants in general, most seeds, for instance, and the winter-buds of trees, are not at all sensitive to cold, whereas, if they contain a considerable quantity of water, as is the case when buds are in process of development and in succulent parts of plants, they freeze very readily. If an organ containing much water be exposed to cold, a certain quantity of water, proportionate to the depression of the temperature, escapes from the cells and freezes on their surfaces, and the tissues contract in proportion; the water does not freeze inside the cells. The frozen water forms an incrustation upon the cells (*K* Fig. 73) of distinct crystals lying parallel to each other consisting of almost pure ice, for the substances held in solution by the water are retained by the remaining cell-sap, which becomes therefore more concentrated. It is certain that a great many plants are not injured by this formation of ice in itself, for, if the thaw is slow, the cells reabsorb the water and return to their normal condition. But if the thaw is effected very quickly, the large quantity of water which is suddenly formed cannot be absorbed with sufficient rapidity by the cells, and it collects in the intercellular spaces: it either induces decay in the

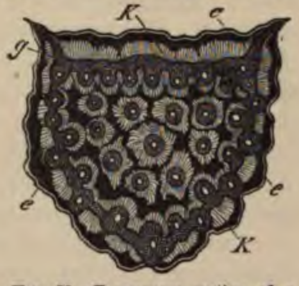


FIG. 73.—Transverse section of a frozen leaf-stalk of *Cynara Scolymus*: *e* the detached epidermis; *g* the parenchyma in which lie the transverse sections of the fibro-vascular bundles (left white). The incrustation of ice (*K K*) consisting of densely-crowded prisms (the cavities of the ruptured tissue are left black in the figure).

plant or it escapes and is evaporated, and the plant dries up. However, many parts of plants, as the leaves of the Pumpkin, cannot be preserved from death even by the most careful thawing.

Frost causes radial splitting of the stems of trees: the fissures close up when the temperature rises, but healing can of course take place only in the cortex. The splitting is due to the unequal contraction of the wood, that of the external parts which contain much water being the greater.

Cold exercises a peculiar influence on many green leaves; the twigs and leaves of Thuja, Ilex, and others, turn to a reddish brown colour in the cold, and become green again under the influence of warmth. This change of colour, usually from green to a light brown, results from a modification of the chlorophyll itself, and must not be confounded with the red colour that many leaves assume in autumn and winter, *e.g.*, of the Virginia creeper, and which is due to the presence of a colouring-matter in solution.

§ 52. **Light,** as has been seen, is indispensable to the formation of starch; but when that process has been accomplished, the subsequent processes of metabolism and growth can go on without the aid of light, though they may be more or less affected by its influence. Shoots can grow from organs containing supplies of nutrient material, such as potatoes, in complete darkness: the growing end of the stem of a vigorous plant, if introduced into a dark chamber, will produce leaves, flowers, and fruit; its nourishment being supplied by the lower leaves which remain exposed to the light. If the modifying influence which light exercises on growth, metabolism, and similar processes, be considered, five sets of effects may be distinguished, which are produced by the action of light upon the vital processes of plants. These fall under two heads:—I. *The chemical effects*, which are produced for the most part by the less refrangible (yellow) rays of the spectrum (in this respect they contrast strongly with the chemical action of light on salts of silver); and II. *The mechanical effects*, which are produced chiefly by the highly refrangible (blue) rays of the spectrum.

The chemical effects are—

I. *The formation of chlorophyll;* this is in so far dependent on light that the colouring-matter cannot acquire its green hue, but remains yellow, although the particles of protoplasm which constitute the chlorophyll-corpuscles become differentiated from the rest of the protoplasm in the dark. The co-operation of light is indispensable to the formation of the green colouring-matter, and this effect is not exclusively confined to the rays of low refrangibility, but is produced to some extent also by those of high refrangibility. In only a few cases—as the seedlings of Conifers and the leaves of Ferns—do the organs of plants turn green in the dark. It must not be forgotten that the formation of chlorophyll depends also on the temperature, and will not take place if it be too low; hence the shoots of plants which break through the soil in very early spring may remain yellow if the weather is cold, in spite of the exposure to light, until warmer weather sets in.

II. The dependence of *the formation of starch* on light has already been pointed out (§ 33); the influence of the rays of high refrangibility is here very slight.

The mechanical effects are—

III. The phenomenon that in many plants a strong light produces a fading of the colour of leaves and other green parts, while those which are shaded remain a dark green. It has been ascertained that this change of colour is due to a change in the position of the chlorophyll-corpuscles in the cells effected probably by the protoplasm. It appears that when the cells are exposed to diffuse daylight, the chlorophyll-corpuscles collect on the upper and lower walls of the cells, or rather, they arrange themselves in planes perpendicular to the direction of the incident ray (*epistrophe*); but when the cells are exposed to bright sunlight, the chlorophyll-corpuscles collect on the lateral walls of the cells, or rather, arrange themselves in planes parallel to the direction of the incident ray (*apostrophe*). Removal of the leaves from diffuse daylight into darkness also produces apostrophe. Many zoo-spores move towards the light while others, on the contrary, avoid it.

IV. Cell-division is independent of light. It frequently proceeds in parts to which no light can penetrate—as in many growing-points and in the cambium—with as much activity as in other parts which are fully exposed to light, as frequently in the formation of stomata. On the other hand, the growth of all those organs which are positively heliotropic is greatly influenced by light; that is to say, that it is considerably retarded: this effect is produced by the more refrangible rays exclusively.

V. Light acts on irritable motile organs in two ways; in the first place an increased intensity of light induces the assumption of the diurnal position (*paratonic action*), in the second place the condition of irritability is intimately connected with the normal exposure of the plant to the influence of light (*phototonus*). (*See* § 50.)

§ 53. **Gravitation.** All plants and all parts of a plant are naturally subject to the action of gravitation. It has already been pointed out (§ 47) how this influences the direction of growth of the organs of plants producing the phenomena of Geotropism. Plants exhibit various adaptations for the purpose of maintaining a definite relation between the weight of their different parts and the discharge of their functions. The rigidity of their woody tissue enables boughs to support the weight of their leaves and fruit; climbing and twining plants avail themselves of foreign bodies for the same end. Water-plants have various appliances, such as air-containing spaces, very much elongated stems, etc., for raising the different parts to the surface of the water. The seeds and fruits of many plants are provided with hairy, feathery, or winged appendages to facilitate their transport by the wind.

§ 54. **Electricity.** The many chemical processes which go on in plants must be accompanied by electrical phenomena. As plants are good conductors, the difference of the electric tension of earth and air is equalised by means of them: that this is the case is shown by the fact that tall trees are frequently struck by lightning. Beyond this little is known. Highly electrical conditions of the atmosphere act upon sensitive leaves, as those of the Mimosa, like mechanical stimuli; and protoplasm, when stimulated electrically, exhibits no special phenomena which might not be produced by other means.

CHAPTER VI.

REPRODUCTION AND ALTERNATION OF GENERATIONS.

§ 55. **Reproduction.** Many plants are reproduced by bulbils (see § 5) which become separated from them; a similar mode of multiplication is effected by stems—more particularly under-ground rhizomes, creeping stems and such like—which branch and constantly die away from behind forwards so that the lateral shoots become so many isolated and independent plants. The branches, and even leaves, of many plants, when artificially severed from them, will take root under favourable conditions, and form new plants. Again, many unicellular plants multiply by division. These various modes of propagation may be grouped together under the head of *vegetative reproduction.*

But, besides this, all plants, with the exception of a few of the lower Algæ and Fungi, exhibit *true reproduction*, that is, reproduction by means of special cells. These cells may be produced in two ways:

(*a*) *Asexually:* The reproductive cell formed in this manner is capable, by itself, of giving rise to a new individual.

In the Thallophytes these cells are known by a variety of names, such as *teleutospores*, *uredospores*, *sporidia*, *stylospores*, *tetraspores*, *zoospores* (when they are motile), *conidia*, or simply as *spores*. In the Muscineæ and in the Vascular Cryptogams they are also termed *spores*, but in the Rhizocarpeæ and in the Selaginelleæ two kinds of spores are present, which are distinguished, on account of their relative size, as *microspores* and *macrospores;* these plants are therefore said to be *heterosporous*. In the Phanerogams the *pollen-grains* represent the microspores, and, like them, are set free from the parent plant: the macrospores find their representatives in certain structures which are contained in the ovule, but which are not set free from the parent-plant. These spores are, however, not always unicellular; those of some Fungi are multicellular, as are also the pollen-grains of Phanerogams.

(*b*) *Sexually:* The reproductive cell formed in this manner is essentially the result of the union of two specialised reproductive cells, neither of which, by itself, is capable of giving rise to a new individual.

The details of the process of union are not the same in all groups of plants, and a prefix is added to the word "spore" to indicate the precise mode in which the sexually-produced reproductive cell has been formed in any particular case. In most Cryptogams the coalescence takes place between two cells which differ greatly both in size and form, of which one is the *male* and the other the *female*, which are developed in special organs termed *antheridia* (male) and *archegonia* or *oogonia* (female). The process is then termed *fertilisation*. In this case the male cell is a small mass of protoplasm, usually without a cell-wall, but endowed with spontaneous motility, which is termed an *antherozoid:* it penetrates into the female reproductive organ and coalesces with the female cell, the *oosphere*, which is likewise a naked primordial cell, but is much larger than the antherozoid and is not motile. As a consequence of fertilisation, the oosphere becomes surrounded by a cell-wall, and is then termed an *oospore*.

But the differentiation of antherozoid and oosphere is not so complete as this in all plants. In the Peronosporeæ, for instance, the oosphere is differentiated, but the antherozoids are not; the protoplasmic contents of the male reproductive organ, which fertilise the oosphere, are quite undifferentiated. This is the case also in Phanerogams; here the fertilisation of the oosphere is effected by means of the undifferentiated protoplasmic contents of those outgrowths of the pollen-grains which are known as *pollen-tubes*. In the Lichens and in the Florideæ the cells corresponding to the antherozoids of other Cryptogams are provided with a cell-wall and are not motile, and in these plants also there is no distinctly differentiated oosphere in the female reproductive organ. In the other Ascomycetes in which sexual reproduction is known to occur, neither antherozoid nor oosphere is differentiated, but the male and female reproductive organs coalesce. These last-named groups of plants have this peculiarity in common, that the product of fertilisation is not a single cell, but a number of cells usually contained in a fructification and therefore termed *carpospores*, those of the Ascomycetes being further distinguished, on account of the mode of their development, as *ascospores*. In certain Algæ and Fungi (Zygosporeæ) the two cells which coalesce are usually similar in size and form, and they are either both stationary or both motile; in this case the process of union is termed *conjugation*, and the resulting cell a *zygospore*. It is of course impossible to say with certainty which of the coalescing cells is male and which female.

In the Thallophytes the sexually-produced reproductive cell (oospore, zygospore, carpospore) is set free from the parent-plant before it germinates: in the Mosses and Vascular Cryptogams the oospore developes whilst still included in parts of the parent-plant; in the Phanerogams also it developes to a certain extent and forms the *embryo*, but at this stage its development is arrested, and it is then thrown off, together with certain parts of the parent-plant, as the *seed*.

Sexual reproduction has not yet been actually observed in the Æcidiomycetes (Uredineæ), but on the ground of analogy, their *æcidiospores* are generally considered to be carpospores like the ascospores of the Ascomycetes.

Instances are on record in which an oosphere has given rise to a new individual without having been previously fertilised by an antherozoid; this has been observed in the Saprolegnieæ and in *Chara crinita*. This is termed *parthenogenesis*.

§ 56. **Alternation of Generations.** In the higher Cryptogams it can be readily observed that a reproductive cell, whether produced asexually or sexually, does not give rise to an individual similar to the one which bore it. If it be a spore, it gives rise to an individual which bears sexual organs; if it be an oospore, it gives rise to an individual which bears spores. Thus there come to be two distinct generations in the life-history of one of these plants, the one, termed the *sporophore*, which is asexual and bears spores, the other, termed the *oophore*, which is sexual and produces the male and female reproductive organs, and these two generations differ considerably from each other in appearance. This is what is meant by the phrase *Alternation of Generations*. In a Moss, for example, the ordinary moss-plant is the oophore; the product of the development of the oospore is not an individual similar to the parent-plant, but a fructification, called the sporogonium, in which spores are formed. When the spore of a Fern germinates, it does not give rise to a fern-plant with stem and leaves bearing spores, but to a small flattened cellular body, the prothallium, which produces the antheridia and archegonia: it is from one of the fertilised oospheres of the prothallium that the ordinary spore-bearing Fern is developed. The alternation of generations becomes more difficult to trace in ascending from the Ferns to the Phanerogams, on account of the gradual diminution in size of the oophore: in the heterosporous Vascular Cryptogams the prothallium does not become free from the spore from which it is developed; the prothallium which is developed from the microspore produces only male organs, and the prothallium which is developed from the macrospore produces only female organs: in the Phanerogams, the pollen-tube alone represents the male prothallium, and, inasmuch as the representative of the macrospore is not set free from the plant which bears it, the structures which represent the female prothallium of the heterosporous Vascular Cryptogams are enclosed in parts belonging to the sporophore. In a Phanerogam, then, the plant is the sporophore, the oophore being only represented by the pollen-tube and by certain cells contained in the ovule.

In the Thallophytes no such alternation of generations can be traced. In some of them, such as Fucus, the only reproductive cells which are formed are oospores: in others the same individual produces spores sexually at one time and asexually at another, and in others again these two processes may go on simultaneously. For these reasons it is impossible to distinguish sporophore and oophore as has been done in the higher Cryptogams and in the Phanerogams.

PART IV.

THE CLASSIFICATION OF PLANTS.

Introductory Remarks. A systematic classification of plants may be arrived at by either of two methods. In the first, the different forms of plants are arranged according to some one given principle; by this means order is established, and a definite position in the system is assigned to each plant. Many such systems have been devised, and are known as *artificial systems*. The principle of classification in such a case must be determined more or less arbitrarily and without considering whether or not, in the resulting arrangement, the plants which are nearly allied are always brought together, and those which are less nearly allied are kept apart. The best known of these artificial systems is that of Linnæus, called the sexual system, which classifies plants by the number and mode of arrangement of the sexual organs. These organs, in his time, were known only in the *Phanerogams* (seed-bearing plants); to the great group of the *Cryptogams*, which Linnæus regarded merely as a subsidiary department of the Vegetable Kingdom, this principle is inapplicable.

The *natural system*, to the gradual development of which a more exact knowledge of the reproduction of Cryptogams has largely contributed, has for its object the classification of plants according to their fundamental relationships, and as these are established once for all by Nature itself, the natural system is not based upon any arbitrary principle of classification, but depends upon the state of our knowledge of these fundamental relationships. These find their expression in the structure and other characteristics of the reproductive organs, as well as in the relation of reproduction to the alternation of generations.

This is more particularly true with regard to the definition of the larger groups of the Vegetable Kingdom; within these groups relationships may be exhibited sometimes in one way and sometimes in another, so that it is not possible to lay down any universal rules for determining close affinities.

As the investigation of this subject is still far from complete, the natural system cannot be regarded as being perfectly evolved;

the various general sketches which have hitherto been given are therefore no more than approximations to the truth. The system laid down in the following table has no pretension to be regarded as the only correct one; it is selected simply because the arrangement it offers appears to answer most nearly to the present state of knowledge of morphology and affinity.

The following Table exhibits, provisionally, the main divisions of the vegetable kingdom :—

1st GROUP. **Thallophyta.** Plants of very simple structure, without any differentiation of leaf and stem, without true roots or fibro-vascular bundles.

Class 1. Algæ.
„ 2. Fungi.

2nd GROUP. **Muscineæ.** The plant which is developed from the spore has generally a distinct stem and leaves, but possesses neither fibro-vascular bundles nor roots, and bears the sexual organs (oophore). The fertilised oosphere gives rise to a capsule containing spores (sporophore).

Class 3. Hepaticæ.
„ 4. Musci.

3rd GROUP. **Pteridophyta.** From the spore a small prothallium is developed which bears the sexual organs (oophore). From the fertilised oosphere a plant is developed consisting of stem, leaves, and roots, containing fibro-vascular bundles and producing spores (sporophore).

Class 5. Filicinæ.
„ 6. Equisetaceæ.
„ 7. Lycopodinæ.

4th GROUP. **Phanerogamia.** These plants are characterized by the production of true seeds containing at maturity a minute plant (embryo), furnished with rudimentary root, stem, and leaves. The ovule contains the oosphere from which the embryo is developed in consequence of fertilisation.

A. **Gymnospermæ.**
Class 8. Gymnospermæ.

B. **Angiospermæ.**
Class 9. Monocotyledones.
„ 10. Dicotyledones.

If the characteristics which are common to several groups be especially considered, the Phanerogams may be distinguished as seed-bearing plants from the three groups of Cryptogams; the Thallophytes and Muscineæ may be distinguished as *non-vascular* plants (*cellular plants*) from the higher Cryptogams and the Phanerogams which are *vascular* plants, and the Thallophytes from the three groups which exhibit a differentiation of leaf and stem, and which are termed *Cormophytes.*

The above-mentioned Classes are of very unequal extent; for while certain of them, as the Equisetaceæ, include few forms and those for the most part very closely allied, others, as the Dicotyledones and the Fungi, include an enormous number of very different forms. These discrepancies arise from the very nature of the natural system, for a great diversity does not necessarily display itself in a type which is represented by a single class, and it must not be forgotten that probably the few living representatives of many Classes, for instance of the Lycopodinæ, are but the surviving remnant of various once well-represented orders which have become in great measure extinct.

Those Classes which include a sufficiently large number of forms are subdivided into subordinate divisions, as (1) Sub-classes, (2) Series, (3) Cohorts, (4) Orders, and these again, if necessary, into Sub-orders, etc.: but these names are applied in the most arbitrary manner to the different sub-divisions. The two narrowest systematic conceptions, viz., Genus and Species, are used to indicate an individual plant. Under the term *Species* are included all individuals which agree so closely that they may be considered as having all descended directly from a common ancestral form. New peculiarities may no doubt—though comparatively seldom—occur in the course of multiplication: the individuals characterized by these new peculiarities are regarded in classification as *varieties* of the species. When several species resemble each other so distinctly that their general appearance indicates a relationship, they are grouped together in a *Genus.* The limits of genera are consequently by no means fixed, but vary according to the views of individual botanists. In the larger genera the species are grouped into *Sub-genera.*

The scientific name of every plant consists—on the plan introduced by Linnæus—of two words, the first indicating the name of the genus, and the second that of the species. Thus, for instance, the greater Plantain, *Plantago major,* and the Ribwort, *Plantago* *lanceolata*, are two species of the genus Plantago. Since in early times the same plants were often described under different names, and as different plants were often designated by the same name, it is necessary in scientific works, in order to avoid confusion, to append to the name of the plant the name of the botanist who is the authority for it. Thus *Plantago lanceolata* L., indicates that Linnæus gave the plant this name, and at the same time that the plant meant is the one which Linnæus described and to which he gave the name. Again, the Spruce Fir is called *Abies excelsa* D. C. (De Candolle), while the same plant was placed by Linnæus in the genus Pinus under the name *Pinus Abies* L.; hence these names are synonymous; but *Pinus Abies* Duroi, is another plant altogether, the Silver Fir.

The method by which each plant has its place assigned to it in the natural system is exhibited in the two following examples—I. *Plantago major;* II. *Agaricus muscarius*:—

I. Group: Phanerogamia.
  Division: Angiospermæ.
    Class: Dicotyledones.
      Sub-class: Gamopetalæ.
        Series: Hypogynæ.
          Cohort: Lamiales.
            Order: Plantagineæ.
              Genus: Plantago.
                Species: Major.

II. Group: Thallophyta.
  Class: Fungi (*Carposporeæ*).
    Order: Basidiomycetes.
      Tribe: Hymenomycetes.
        Family: Agaricinæ.
          Genus: Agaricus.
            Sub-genus: Amanita.
              Species: Muscarius.

GROUP I.

THALLOPHYTA.

This group includes the lowest forms of vegetable life. They present no differentiation of stem, leaf, and root, and some of them are unicellular, the entire organism consisting of a single cell. In the lowest members of this group there is no sexual reproduction; in the higher, the product of sexual union may be a zygospore or an oospore, or a mass of carpospores, or a fructification within which carpospores are formed. The division of the group into the two classes Algæ and Fungi is artificial, in that it is based upon the presence (Algæ) or absence (Fungi) of chlorophyll. Still it is probable that these classes are on the whole really natural, and that the evolution of higher forms proceeded equally in both.

General Classification of Thallophytes.

A. *Protophyta.*
No sexual reproduction.

Algæ.	*Fungi.*
Phycochromaceæ.	Schizomycetes.
	Saccharomycetes.

B. *Zygosporæ.*
Sexual reproduction by conjugation.
Product, a zygospore.

Conjugatæ.	Zygomycetes.
Zoosporeæ.	Myxomycetes (?).[*]
Botrydiaceæ.	Chytridiaceæ.

C. *Oosporeæ.*
Sexual reproduction by fertilisation.
Product, an oospore.

Siphoneæ.	Saprolegnieæ.
Volvocineæ.	Peronosporeæ.
Œdogonieæ.	Entomophthoreæ (?).
Coleochæteæ.	
Characeæ.	
Melanophyceæ.	

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[*] The note of interrogation indicates that the occurrence of sexual reproduction has not been definitely ascertained in the Order to which it is appended.

D. *Carposporeæ.*
Sexual reproduction by fertilisation.
Product, numerous carpospores.

Algæ.	*Fungi.*
Florideæ.	Ascomycetes.
	Uredineæ (Æcidiomycetes) (?).
	Ustilagineæ (?).
	Basidiomycetes (?).

Class I.—ALGÆ.

These are plants of the simplest structure, which either live in water in the form of green, blue-green, or brownish filaments or masses of cells, or clothe damp surfaces such as rocks, walls, or the bark of trees, with a covering of one or other of these colours. In the sea they attain often a very considerable mass; some of them are of a beautiful red or brown colour, and attract the attention of the observer, partly by their gigantic size and partly by the elegance of their ramification. Whilst some are unicellular, existing throughout their whole lives as single cells and producing new individuals by division, others form long rows of cells, or considerable masses or extended surfaces of cellular tissue.

The most important feature in which the plants of this Class differ from the Fungi is the presence of chlorophyll and the consequent mode of life. The Algæ are able to form the organic substances necessary for their nutrition, whereas the Fungi are obliged to obtain them from other organisms. The presence of chlorophyll is obvious enough in the green Algæ, but it exists also, though less evidently, in Algæ which have a bluish-green, olive-green, brown or red colouring-matter in addition in their chlorophyll-corpuscles. The nature of this additional colouring-matter is usually the same throughout whole families which also resemble each other in their modes of reproduction.

The reproduction of the Algæ, when it is not merely a process of division, is effected by cells which are produced sexually or asexually. The former are designated by terms which indicate the special mode of their development (*zygospore*, *oospore*, *carpospore*): the latter are spoken of generally as *spores* (*zoospores* when they are motile). Reproduction by means of zoospores is very common in this class (Figs. 37 and 80): these are small protoplasmic bodies, without cell-walls, formed either by the division or the rejuvenescence of a cell, which move through the water by means of delicate filaments, the *cilia:* after a time they come to rest, become invested by a cell-wall, and give rise to new individuals by growth and cell-division.

In the very lowest forms reproduction is effected neither sexually nor by means of zoospores. In the Conjugatæ the entire contents of two cells unite to form a zygospore. In many Zoosporeæ two zoospores, which may or may not be exactly similar and which are usually formed by cell-division, coalesce to form a zygospore. To these naturally follow those orders in which only the small male cells (antherozoids) are motile, the female cells being the oospheres which remain in their mother-cells (oogonia) and are converted into oospores in consequence of fertilisation. The oospores may or may not be invested by special integuments, and, on germination, may give rise to one or more individuals. From these the Florideæ differ in the peculiar structure of the female organs and in the formation of a number of reproductive cells, the carpospores. On the other hand the Zoosporeæ resemble the Botrydiaceæ, which have only lately been accurately studied; but there is this difference, that the zygospore of the former group undergoes a period of rest before it germinates, whereas that of the latter germinates immediately after its formation. This is also the case with the oospore in the Melanophyceæ, so far as their mode of reproduction is known at present; in them the oosphere, though it is set free before fertilisation, is not motile.

If, in addition to the modes of reproduction, the general vegetative structure of the Algæ be considered, a classification such as the following may be constructed. This must of course be considered as only provisional, since the reproduction of many forms is still unknown, and it is therefore only possible to assign them a systematic position by a consideration of their vegetative structure.

I. Sexual reproduction unknown; no zoospores.
    Order 1. Phycochromaceæ; bluish-green Algæ.
II. Sexual reproduction, effected by the conjugation of the entire contents of two stationary cells.
    Order 2. Conjugatæ.
III. Sexual reproduction, effected by the conjugation of zoospores.
    Order 3. Zoosporeæ; the product of conjugation is a resting zygospore.
    Order 4. Botrydiaceæ; the product of conjugation is a zygospore which germinates at once.

IV. Sexual reproduction (so far as is at present known), effected by the fertilisation of a free oosphere; from the oospore a new individual is directly developed.

Order 5. Melanophyceæ.

V. Sexual reproduction, effected by fertilisation within special female organs (Oogonia and Carpogonia).

A. The thallus a single, much-branched, filamentous cell.

Order 6. Siphoneæ. The oospore gives rise to a single new individual: female organ an oogonium.

B. The thallus is multicellular.

(*a.*) *Female organ an oogonium.*

Order 7. Volvocineæ: thallus motile.

Order 8. Œdogonieæ: thallus filamentous.

Order 9. Coleochæteæ: thallus consisting of rows of cells: oospore with a special cellular investment.

Order 10. Characeæ: the oosphere has a cellular investment before fertilisation.

(*b.*) *Female organ a carpogonium.*

Order 11. Florideæ (red Algæ): the female organ has a complicated structure: numerous spores produced in consequence of fertilisation.

1. Phycochromaceæ, or blue-green Algæ. Neither sexual reproduction nor formation of zoospores is known in this order: multiplication is effected most frequently by cell-division, which takes place in some cases in more than one plane, but sometimes also by means of spores. Several of the genera are unicellular, *e.g.*, Glœocapsa (Fig. 74), Chroococcus and others. The separate individuals are sometimes enveloped in a gelatinous diffluent membrane, and are thus united into colonies or families forming a blackish or dark-blue film on rocks or Mosses. Others appear as many-celled filaments: Nostoc (Fig. 75 *A*) for instance, consists of rows of cells forming brownish gelatinous masses which are often to be found after wet weather on paths or sandy soil; in a dry state they are inconspicuous and of a dark colour. The Oscillarieæ (Fig. 75 *B*), the filaments of which exhibit peculiar locomotor movements, are often seen as blue-green or brown-green patches floating

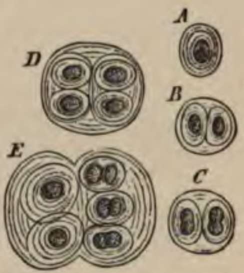


Fig. 74.—Glœocapsa (× 300) in various stages. *A* becomes *B*, *C*, *D*, *E* by repeated division. (From Sachs.)

on stagnant waters and having a very disagreeable smell. The Rivulariæ form cushion-like patches consisting of a gelatinous matrix, in which the filaments are disposed radially; they occur on submerged stones and water-plants.

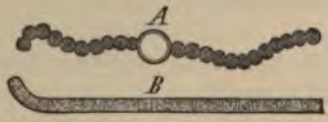


FIG. 75.—*A* Filament of Nostoc. *B* End of a filament of Oscillaria (× 300).

2. The CONJUGATÆ are distinguished by the process of conjugation which takes place between the whole of the protoplasmic contents of the cells in the process of reproduction. Zoospores are not formed. They are subdivided into three families:

a. The *Zygnemaceæ*, consisting of long unbranched filaments which occur in large floating patches in many waters, particularly ponds and springs; they are easily recognised by their bright green or yellowish colour as well as by the delicacy of their filaments. Their chlorophyll-corpuscles have peculiar forms: in Spirogyra they are spiral bands (Fig. 40); in Zygnema, stars (Fig. 76 *A*); in Mougeotia, plates.

b. The *Desmidiaceæ* include unicellular forms, which are often extremely beautiful, as Closterium (Fig. 76 *B*), Cosmarium, Staurastrum, Euastrum (Fig. 76 *C*).

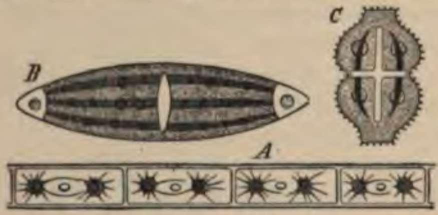


FIG. 76.—*A* Fragment of a filament of Zygnema; in each cell are two star-shaped chlorophyll-corpuscles connected by a colourless mass of protoplasm in which lies the nucleus. *B* Closterium, *C* Euastrum, two Desmids with chlorophyll-plates.

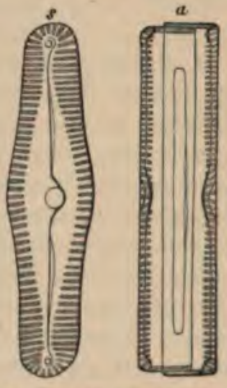


FIG. 77.—Pinnularia, a Diatom (mag. and diag.); *a* lateral view, showing the mode of connection of the two halves of the frustule; *s* surface view.

c. The *Diatomaceæ*, in which the chlorophyll-corpuscles are of a dark-yellow colour. The individuals are unicellular; the cell-walls contain much silica, and exhibit extremely delicate and elegant thickenings. The wall (frustule) of each cell consists of two halves which fit into each other like the two parts of a pill-box (Fig. 77 *a*). Division takes place lengthwise between the two halves, and the newly-formed wall of the daughter-cell is enclosed within the rim of that of the mother-cell, so that the two halves of the cell-wall are of different ages. In consequence of repeated division the individuals must grow smaller; when this diminution has gone on to a certain extent the formation of *auxospores* takes place, that is of very large cells, either by means of growth alone or as the result of conjugation and subsequent growth. In some genera, *e.g.*, Navicula and Pinnularia (Fig. 77) the individuals are solitary and they are endowed with a peculiar creeping mode of locomotion. In others, as Melosira, they are arranged in long filaments. They occur frequently and in great numbers in all waters, fresh as well as salt, sometimes also in damp soil between Mosses. The siliceous frustules of Diatoms have been preserved from the early geological epochs and exist in various parts of the world in great masses, under the name of infusorial earth.

3. The ZOOSPOREÆ are reproduced by means of zoospores which, in the case of many forms at least, conjugate, and give rise to resting zygospores.

Some families, such as the *Hydrodictyeæ* consist of unicellular forms which generally live together in colonies (Fig. 78 *A*). The whole colony is usually actively motile by means of the cilia of its individual members. Periods of rest sometimes alternate with periods of movement, and these resting forms were formerly regarded as being distinct plants; such are many Palmellaceæ and perhaps *Pleurococcus vulgaris*, which is constantly found as a green growth on the trunks of trees and in similar situations. Hæmatococcus lives in puddles; the resting-cells are of a purplish-red colour and where they occur in masses they impart a red hue to the water or to the snow (red snow).

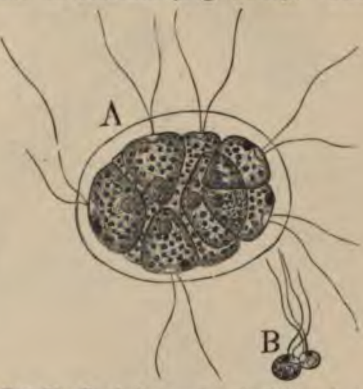


FIG. 78.—*Pandorina morum* (× 400). *A*, a motile colony (cœnobium): *B*, two zoospores, formed by the division of the cells of *A*, in process of conjugation.

The *Confervеæ* are filiform Algæ which are widely distributed in all waters, being especially abundant near their margins; the zoospores are formed in the individual cells, either in considerable numbers or one only in each. The filaments of Cladophora are much branched and are harsh to the touch. The filaments of

Ulothrix are simple; in this plant certain larger zoospores reproduce it vegetatively, whereas the smaller ones conjugate and reproduce it sexually; Chroolepus is orange-coloured, and grows on damp rocks, etc., in velvety patches.

In the *Ulvaceæ* the polyhedric cells are united into flat expansions; in *Ulva Lactuca*, which is a common green sea-weed, the membranous expansion may be simple or more or less branched; in Enteromorpha it forms the wall of a tube.

4. The BOTRYDIACEÆ are represented in fresh water by Botrydium alone. This is a small unicellular plant, looking like a green spheroidal vesicle with colourless root-like outgrowths which attach it to the mud in pools. It is reproduced in several ways; the most remarkable, perhaps, is the formation within the vesicle of the so-called "spores," each of which gives rise to a large number of conjugating zoospores.

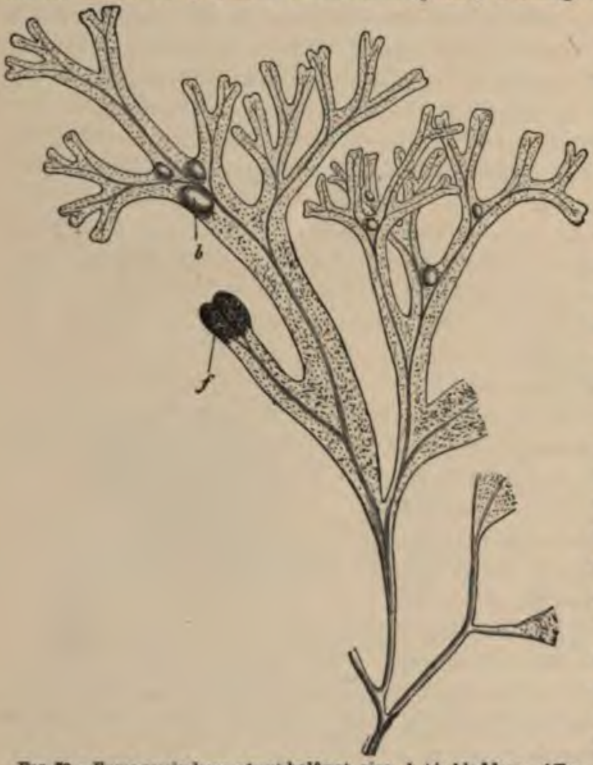


FIG. 79.—*Fucus vesiculosus*, about half nat. size. *b* Air-bladders. *f* Fertile branch.

5. MELANOPHYCEÆ. These are the brown sea-weeds. Their chlorophyll-corpuscles are of an olive-green colour. They are usually of a considerable size, and present great variety of form. The thallus consists sometimes simply of rows of cells, sometimes of masses of

tissue; it often attains gigantic dimensions, and appears to branch dichotomously. The cell-walls are very mucilaginous. Some are provided with large cavities filled with air (Fig. 79 *b*), by means of which they are enabled to float.

The reproductive organs are borne by certain branches of the thallus (Fig. 79). They are developed in peculiar depressions of the surface, the *conceptacles*. The antherozoids are formed in certain cells termed antheridia, and the oospheres in certain cells termed oogonia. The oospheres are extruded from the oogonia and are then fertilised by the antherozoids. The oospore at once developes into a new individual.

The different species of Fucus and of Laminaria are typical representatives of this order.

6. The SIPHONEÆ are unicellular, but the tubular cells are large and much branched. The different species of Vaucheria (Fig. 80) are frequently found in springs, in wells, and on damp soil, in large dark-green patches. Zoospores are developed in special cells formed by the cutting off, by means of septa, of some of the branchings of the main cell (Fig. 80 *A*). Sexual reproduction is

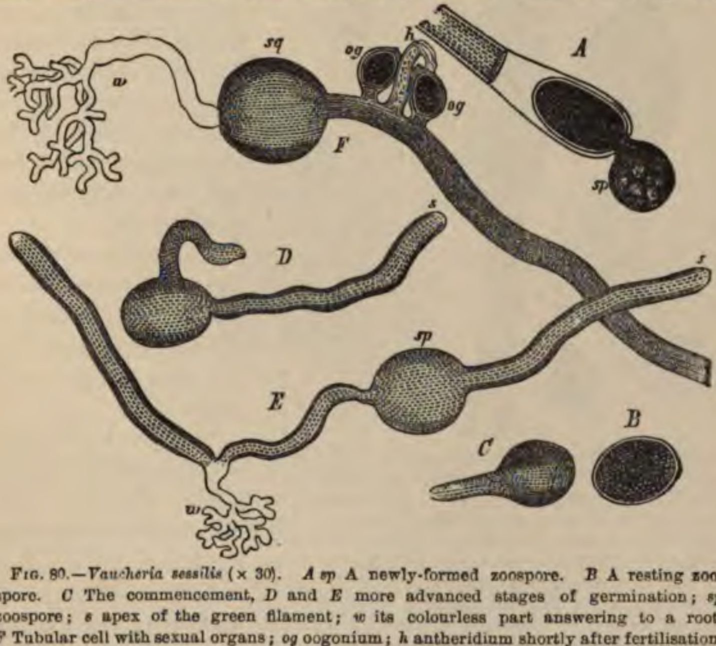


FIG. 80.—*Vaucheria sessilis* (× 30). *A sp* A newly-formed zoospore. *B* A resting zoospore. *C* The commencement, *D* and *E* more advanced stages of germination; *sp* zoospore; *s* apex of the green filament; *w* its colourless part answering to a root. *F* Tubular cell with sexual organs; *og* oogonium; *h* antheridium shortly after fertilisation. (After Sachs.)

effected by antheridia and oogonia. The antheridia are cells, usually curved into a hook-shape, which are developed as lateral branches. Within them the antherozoids, which are subsequently discharged, are formed. The oogonia are spherical cells, developed close to the antheridia, in which the oosphere is formed by rejuvenescence (Fig. 80 *F*, *og*). After fertilisation the oosphere becomes surrounded by a proper membrane, and is then known as the oospore. Whether or not the very large forms found in the sea, *e.g.*, Caulerpa, consisting of a single much-branched cell, really belong to this order, is at present uncertain, for their reproduction has not been fully investigated as yet.

The order of the Siphoneæ appears to be more closely allied to the Saprolegnieæ (Fungi) than to the other Algæ.

7. The VOLVOCINEÆ, as represented by the genus Volvox, are closely allied in their structure to the Zoosporeæ which live in colonies; the colony here takes the form of a hollow sphere. Fertilisation is, however, not effected by the conjugation of zoospores; but the oosphere, which is stationary, is fertilised by antherozoids.

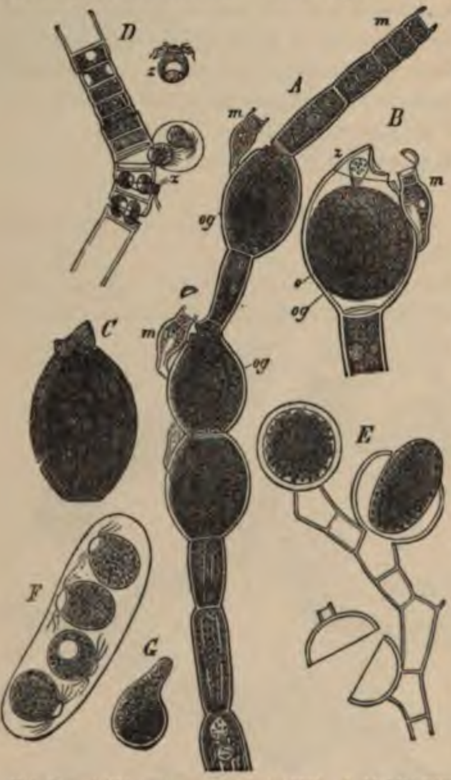


FIG. 81.—*A Œdogonium ciliatum* (× 250). A Middle part of a sexual filament with two oogonia (*og*) fertilised by the dwarf male plants (*m*), developed from zoospores formed in the cell *m* at the upper part of the filament. *B* Oogonium at the moment of fertilisation; *o* the oosphere; *og* the oogonium; *z* the antherozoid in the act of forcing its way in; *m* dwarf male plant. *C* Ripe oospore. *D* Piece of the male filament of *Œd. gemelliparum*, *z* antherozoids. *E* Branch of a *Bulbochæte*, with one oogonium still containing a spore, another in the act of allowing it to escape; in the lower part an empty oogonium. *F* The four zoospores formed from an oospore. *G* Zoospore from an oospore come to rest. (After Pringsheim.)

8. The Œdogonieæ occur in green patches in springs and other waters. These patches are composed of cellular filaments, of which the separate cells sometimes produce zoospores, and sometimes become oogonia, the contents of each one being converted into an oosphere by rejuvenescence (Fig. 81 *B*). The antherozoids, which resemble the zoospores but are smaller, are produced in some species by repeated division in the cells of the filaments (Fig. 81 *D*); but in other species the cells of the filament give rise to peculiar zoospores which adhere to the oogonium and grow into *dwarf males* consisting of but few cells (Fig. 81 *A m*), in which the antherozoids are formed.

9. The Coleochæteæ form hemispherical or disk-shaped cushions of a beautiful green colour on submerged stones and water-plants.

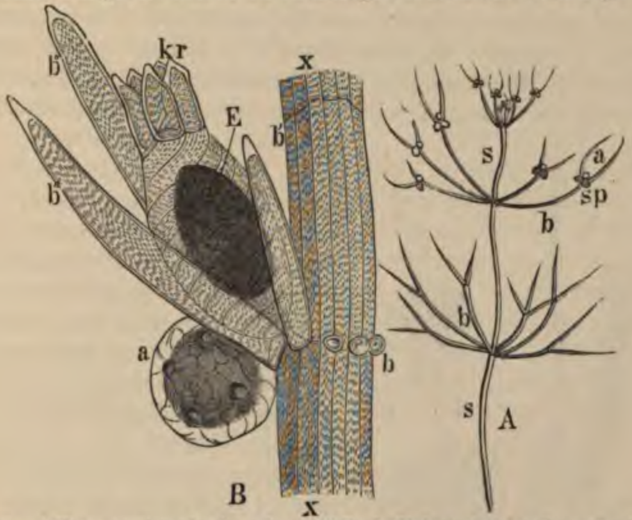


Fig. 82.—*A* Upper portion of a branch of *Nitella flexilis* (nat. size); *ss* the stem; *b* the leaves; with *sp* the female, and *a* the male organs. *B* Part of a fertile leaf *xx* of *Chara fragilis* (× 50); *b b′* the leaves: the female organ contains the oosphere *E*. The peculiarly twisted investing-cells of the oogonium end in a little corona, *kr*: *a* the antheridium. (After Sachs.)

The female organ is unicellular, and presents a long tubular projection open at the apex, the *trichogyne*. After fertilisation the oosphere in the basal dilated part of the oogonium becomes invested by a special membrane; the oogonium becomes surrounded by outgrowths from neighbouring cells, so that it is enclosed in a cellular integument. On germination, the oospore divides, and from the cells thus formed there escape zoospores, which subsequently give rise to new individuals.

10. Characeæ. These are the only green Algæ which, like the Florideæ, have members that can be regarded as leaves. In the genus Nitella (Fig. 82 *A*), inhabiting waters, which are not hard, each internode of the stem consists of a single cylindrical cell (Fig. 82 *A s*), the wall of which is lined by a compact layer of chlorophyll-corpuscles. The so-called leaves (Fig. 82 *A*, *b*) form whorls at the nodes and each consists of a row, sometimes branched, of elongated cells all similar in form. In the other genus, Chara, of which numerous species occur in many waters, and which are remarkable for their unpleasant smell, the stem and leaves are covered with small cortical cells. In all the long cells a rapid rotation of the protoplasm is perceptible. The female organ is an egg-shaped body (Fig. 82 *B*); it possesses a covering of cells twisted spirally, which encloses the oogonium. The oosphere becomes an oospore in consequence of fertilisation, and remains enclosed in the integument. The antheridia (Fig. 82 *a*) are visible as small red spheres; within them the spiral antherozoids are produced in rows of cells.

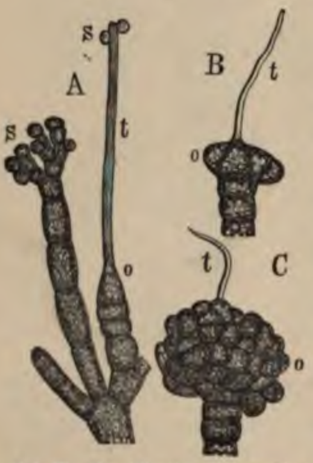


Fig. 83.—Fructification of Nemalion. *A* The end of a branch with a male and a female organ; the former produces the antherozoids, the latter consists of the trichogyne *t*, to which the antherozoids *s* adhere to effect fertilisation, and of the base *o*, from which the cystocarp (*B* and *C*) is developed (× 300).

11. The Florideæ, or red Algæ, are of a beautiful red or violet colour, and live in the sea; only a few forms, such as *Batrachospermum moniliforme*, of a purplish-brown hue, are found in fresh water. Many representatives of this class are distinguished by their graceful branching; and in several genera, *e.g.*, Polysiphonia, it is of such a nature as almost to justify the designation of some of the branches as leaves. Reproduction is effected in a peculiar manner. The female organ, which is termed a carpogonium, is frequently multicellular. Fertilisation takes place by means of antherozoids which, having no cilia, are not motile (Fig. 83 *A s*). They attach themselves to a projecting cell of the female organ, the trichogyne (Fig. 83 *t*), which is, however, not open, like that of Coleochæte, but completely closed; in consequence of fertilisation, a *cystocarp* is formed

from the basal portion of the trichogyne, or more frequently from cells which surround its base, or from others more remote from it. The cystocarps are either masses of carpospores (Fig. 83 *C o*), or receptacles, within which carpospores are formed. The asexually-produced spores (*tetraspores*) are also devoid of cilia, and are passively floated about by the water.

Callithamnion corymbosum*, *Ceramium rubrum*, *Chondrus crispus (used in medicine as Carrageen Moss), ***Plocamium coccineum*, *Delesseria hypoglossum*** and ***Corallina rubens*,** are common representatives of this class in European seas.

CLASS II.—FUNGI.

This class, like the preceding, includes many very simple organisms, as well as others of tolerably high development. None of them contain chlorophyll, and their mode of life is correlated with this peculiarity. They must take up their nourishment, and more especially their Carbon, in the form of organic compounds. Some, termed *Parasites*, such as Rust and Smut, absorb it from living organisms, plants or animals. Others, called *Saprophytes*, absorb it from the remains of dead organisms, or from organic compounds formed by living organisms: the bark of trees and the humus or leaf-soil of forests and meadows are examples of the former case, and they support numerous and often large Fungi; the juice of fruits and saccharine solutions are examples of the latter case, and in these Moulds and Yeasts often make their appearance (see § 33).

In Fungi the cells are usually arranged in rows, so as to form long filaments called *hyphæ:* these are loosely and irregularly interwoven (*tela contexta*), as in the common Mould; but sometimes they are firmly connected into a mass of considerable size, of definite external form and internal structure, as in Mushrooms. A few Fungi only consist of small isolated cells, or of long branched tubular cells, like the Siphoneæ among the Algæ. The thallus developed from the spore, when it is not unicellular, consists of hyphæ, and is called a *mycelium*. The organs of reproduction are usually developed upon some part of the mycelium, but, if circumstances be unfavourable, the mycelium may continue to vegetate for a long time, attaining a most luxuriant growth, without bearing any reproductive organs. The white felt-like growth which often clothes the walls of damp cellars is a sterile mycelium of this kind.

The reproductive cells of Fungi are formed in two ways: in the one, the protoplasm of the mother-cell divides into a number of cells, that is, free-cell formation takes place within it (spores, ascospores); in the other, segments are cut off from the mother-cell by abstriction (stylospores), a process which differs from that of ordinary cell-divisions only in the marked constriction of the cell in the plane of division. The cells which undergo this abstriction are called *basidia*, and they frequently bear a delicate projection, the *sterigma*, at the end of which the spore is borne. In some Fungi the cells formed by the first of these two methods are naked masses of protoplasm, and move actively in water; they are called zoospores. The lowest Fungi are not reproduced sexually, and this is probably also true of some which are more highly organized. Sexual reproduction is exhibited in the form of conjugation by the Zygomycetes, in which branches of the mycelium coalesce, and in the form of fertilisation, closely resembling conjugation, in other Phycomycetes as well as in many Ascomycetes. Other Ascomycetes (and perhaps the Uredineæ) have female organs which resemble the carpogonia of the Florideæ, and which are fertilised by small cells, the *spermatia*, which are passively conveyed from place to place. These cells are formed by abstriction in certain receptacles called *spermogonia*. In the following account of the various groups of Fungi, as in the case of the Algæ, the reproductive cells which are produced asexually are spoken of as *spores* or *conidia* (stylospores, zoospores, etc.), whereas those which are produced sexually are spoken of as *zygospores*, *oospores*, *carpospores* (*ascospores*, *æcidiospores*).

The following remarks are explanatory of the arrangement of the Fungi which is adopted here. In the Phycomycetes sexual reproduction is effected by the conjugation of two hyphæ, or by a process which differs but little from this. The product is a resting-spore which, on germination, may give rise to an individual bearing conidia, or simply to a sporangium.

The Ascomycetes are probably nearly related to the Phycomycetes. In them the sexual process is of much the same kind; but the product is not a single cell, but a number of cells (ascospores) contained in receptacles called *asci*. These asci are more or less enclosed in the mycelial tissue, and these together form a fructification. The mycelium bears, in addition to the sexual organs, numerous organs which reproduce it vegetatively.

The greatest difficulties are offered by those Fungi the reproductive cells of which are formed by abstriction. In the Uredineæ the æcidium-fruit is probably the sexually-developed fructification, or it is at least analogous to such a fructification, whereas the other fructifications are probably produced asexually. No sexual organs have been discovered as yet in the Basidiomycetes, and their large fructifications may therefore be regarded as organs effecting asexual reproduction.

As to the relationship between Fungi and Algæ, the Schizomycetes and the Phycochromaceæ appear to be allied, and they are connected by intermediate forms. Resemblances also exist between the Chytridiaceæ and the lowest Zoosporeæ. It seems probable that the divergence of the two classes began at the first indication of sexual differentiation. In the lower Algæ the zoospores conjugate, and the connection of the more complicate sexual processes of the higher Algæ with this simplest form can be readily traced. In the lower Fungi, excepting the Chytridiaceæ and the Myxomycetes, the cells which correspond to the mother-cells of the zoospores of the Algæ are those which conjugate.

The Entomophthoreæ are perhaps intermediate forms between those Fungi in which the conidia are formed in the interior of mother-cells and those in which they are formed by abstriction. Their sporangia may be compared with those of the Peronosporeæ on the one hand, and with the conidia of the Uredineæ and Basidiomycetes on the other.

The following is an attempt to classify the Fungi in accordance with the present state of our knowledge:

I. Sexual reproduction unknown: multiplication by cell-division or by spores.
  Order 1. Schizomycetes.
  Order 2. Saccharomycetes.

II. The mycelium (if present) consists of a single tubular, much-branched cell: spores are formed in sporangia: sexual reproduction occurs in the form of conjugation, or of fertilisation, the product being (except in Myxomycetes) a resting spore (*Phycomycetes*).

(a.) *Sexual reproduction by conjugation.*
  Order 3. Zygomycetes. Mycelium, a tubular cell: spores non-motile (the sporangium is sometimes thrown off as a conidium).
  Order 4. Chytridiaceæ. Mycelium usually absent: zoospores.
  Order 5. Myxomycetes. No mycelium. The plasmodium, formed by the coalescence of the amœboid masses of protoplasm set free from the spores, is motile.

(b.) *Sexual reproduction by fertilisation.*
  Order 6. Saprolegnieæ. Mycelium, a tubular cell: zoospores.

Order 7. Peronosporeæ. Mycelium, a tubular cell: zoo spores are formed in the sporangium which is thrown off as a conidium.

Order 8. (?) Entomophthoreæ.

III. The mycelium consists of multicellular hyphæ. The presence of sexual organs has been ascertained in some members only.

(a.) *Spores formed in the asci of a fructification.*

Order 9. Ascomycetes.

(b.) *Spores formed by abstriction or by simple cell-division.*

Order 10. Ustilagineæ. The spores are formed by division of the hyphæ.

Order 11. Uredineæ. The spores, which are usually of different kinds, are formed by abstriction or by cell-division at one point only of each basidium, partly in small fructifications (perhaps sexually produced) and partly on the mycelium.

Order 12. Basidiomycetes. The spores, which are all of one kind, are formed by abstriction at different points on each basidium in asexual fructifications.

1. The SCHIZOMYCETES are very minute organisms, of which little more than the outline can be detected; they are therefore very easily confused with altogether different objects. The cells may be either isolated, and then spherical (Micrococcus, Fig. 84 *a*), or rod-like (Bacterium, Fig. 84 *b*), or united into filaments which may be straight (Bacillus) or spirally wound (Spirillum, Fig. 84 *c*). They generally multiply by division, but in Bacillus spores are formed: certain cells of the filaments undergo divisions, and the cells thus formed are distinguished by their longer persistence, and their power of resisting injurious influences. Some forms produce colouring-matters in the course of their life (such as that causing the red colour of mouldy bread); others play a part in certain infectious diseases, such as Diphtheria, Cholera, Typhus, etc.

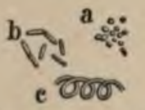


FIG. 84.—Schizomycetes (× 500). *a* Micrococcus; *b* Bacterium; *c* Spirillum.

2. SACCHAROMYCETES. These Fungi occur in fermenting substances. The mycelium consists of branched rows of oval cells, produced by successive budding: the cells separate very easily from each other. Spores are produced in the cells under certain circumstances: they are four in number in each cell. These

Fungi have the power of converting the sugar contained in the substance upon which they live into alcohol and carbonic acid.

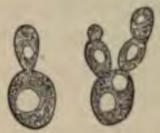


FIG. 85.—Growing cells of Yeast (*Saccharomyces Cerevisiæ*) (× 300).

Saccharomyces Cerevisiæ, the ordinary yeast (Fig. 85), is only known in the cultivated state in which it is used in brewing, etc. *S. ellipsoideus* occurs in nature on the surface of fruits, such as grapes, and causes the fermentation of their juices after they have been crushed. *S. Mycoderma* belongs to this group: it exists on the surface of fermented fluids and causes their further decomposition.

3. ZYGOMYCETES. Of these, the most common and the most important are the species of the genus Mucor, such as *Mucor Mucedo*, *racemosus*, *stolonifer*, which occur as mould on preserves, bread, etc. The mycelium is much branched, but consists only of a single cell (Fig. 86 *m*): it grows in the substance and, when mature, throws up aërial branches. These become enlarged at their free ends, and by the cutting off of the enlargement by a curved partition, the sporangium is formed, within which numerous spores are formed (Fig. 86 *s*). On germination, each spore gives rise to a new mycelium, which, in its turn, bears sporangia and spores. Under certain circumstances the mycelium bears zygospores (Fig. 87 *z*). Two branches of the mycelium come into contact at their free ends, and a cell is cut off in each by the formation of a septum: the two cells coalesce (conjugate) to form a single cell, the zygo spore: its cell-wall becomes much thickened. After a long period of quiescence it germinates, and it usually produces a single hypha

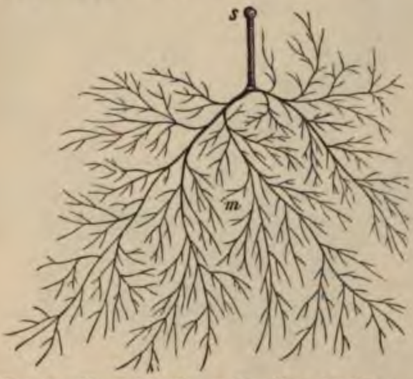


FIG. 86.—*Mucor Mucedo*. *m* Mycelium bearing a sporangium (*s*).

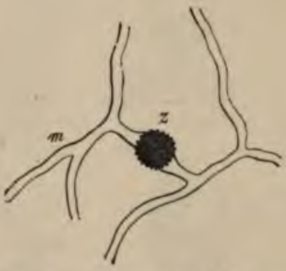


FIG. 87.—Zygospore (*z*) of Mucor.

bearing a sporangium quite similar to those borne by the ordinary mycelium.

4. The CHYTRIDIACEÆ are among the lowest of the Phycomycetes. Some of them consist of a single spherical or oval cell, which itself becomes a sporangium, its protoplasm giving rise to a number of zoospores. When one of these zoospores comes to rest, it assumes the spherical form. Conjugation of both motile and stationary cells has been observed in members of this Order, the former in Polyphagus and Zygochytrium, the latter in Tetrachytrium. These forms live in water either as saprophytes, or as parasites upon aquatic plants. The genus Synchytrium includes forms which are parasitic upon land-plants, such as Anemone and Taraxacum: in these the single cell gives rise to several sporangia.

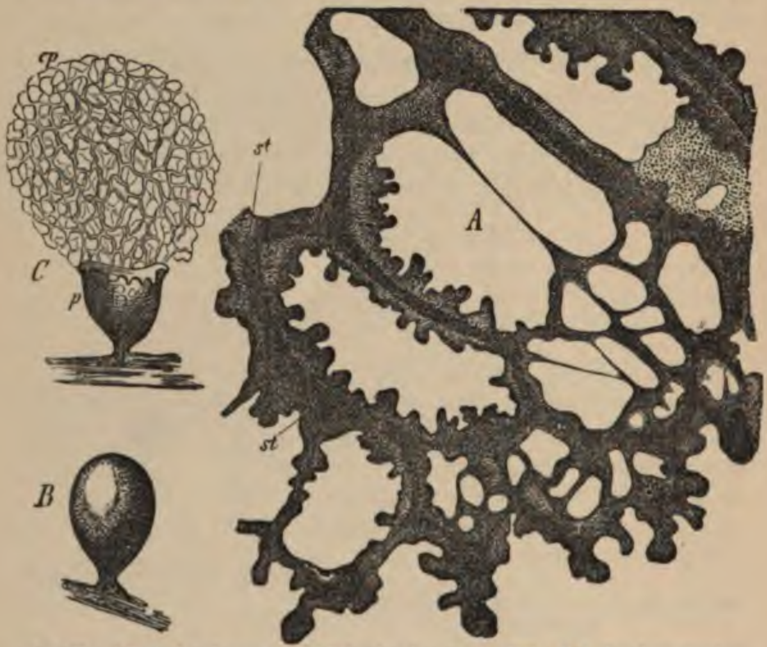


FIG. 88.—*A* Part of a plasmodium of *Didymium leucopus* (× 300). *B* A closed sporangium of *Arcyria incarnata*. *C* The same after the rupture of its walls (*p*) and expansion of the capillitium *cp* (× 20). (After Sachs.)

5. MYXOMYCETES. In the mode of development of their spores these plants resemble the Zygomycetes, but in their structure they differ widely from all other Fungi. In the vegetative condition they do not consist of cells or tissues, but they are simply masses

of naked protoplasm, called *plasmodia* (Fig. 88 *A*), creeping from place to place on the substratum, which may be tan, earth, decayed leaves, etc. At the same time a rapid streaming may be observed in the protoplasm itself. When it is reproducing itself, the whole plasmodium is converted into sporangia, which are spherical bodies resembling the fructifications of Truffles (Fig. 88 *B*); in these the spores are formed. In some cases the whole of the contents of the sporangium are converted into spores; in others, a part of them go to form the capillitium (Fig. 88 *cp*), which is a network of filaments. On germination, the protoplasm of each spore is set free, and either creeps about in an amœboid manner, or swims as a zoospore. These isolated masses of protoplasm unite in great numbers to form the large plasmodia.

Æthalium septicum, the "flowers of tan," occurs in the form of yellow plasmodia, which may be several square inches in extent, on spent tan: it forms masses of sporangia which are yellow externally and dark brown internally.

Trichia rubiformis and *Didymium serpula* are smaller forms which are commonly found in forests. The sporangia of the former are brown oval bodies, from 2–3 mm. in length; they occur in groups on leaves or among Moss.

6. The SAPROLEGNIEÆ are aquatic Fungi. The branched unicellular mycelium forms a dense growth upon the dead bodies of small animals or on parts of plants which are in water. Correlated with their mode of life is the fact that the reproductive cells formed in their sporangia are zoospores. Sexual reproduction is effected not by conjugation but by fertilisation. The organs are of two kinds: there are oogonia, which are spherical cells each containing several oospheres, and there are antheridia from which protuberances are developed which enter the oogonia and effect the fertilisation of the oospheres. The resulting oospores germinate after a period of quiescence and develope either zoospores or a mycelium bearing sporangia.

7. The PERONOSPOREÆ are parasitic upon other plants. The unicellular mycelium permeates the intercellular spaces of their tissues and absorbs nourishment by means of special organs from the neighbouring cells. Sporangia are formed on certain branches which usually project through the stomata of the host (Fig. 89): these are thrown off entire and

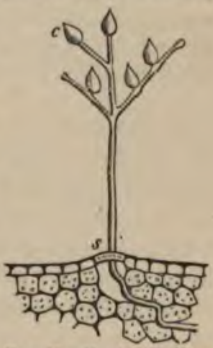


FIG. 89.—Hypha of *Phytophthora infestans* bearing sporangia projecting from a stoma (*s*) of the leaf of the Potato; *c* the sporangia (× 150).

are therefore usually spoken of as conidia. If they fall into a drop of water zoospores are formed within them, which are set free: when these come to rest they attach themselves to the cuticle of their host, become invested by a delicate membrane, and then germinate. In some no formation of zoospores takes place, the sporangium itself developing a mycelium. In the forms in which sexual reproduction is known, the antheridium applies itself to the oogonium, and the oosphere contained in the latter becomes fertilised and is converted into an oospore. The germination of the oospore takes place after a long period of quiescence; usually zoospores are formed within it.

In the genus Peronospora, which is represented by many species (*P. parasitica* on Capsella, *P. nivea* on Umbelliferæ, etc.), only one sporangium is borne by each branch of the hypha which protrudes through a stoma. In Phytophthora the sporangia are displaced laterally by branches which arise from the hyphæ bearing the sporangia, at their points of origin. To this genus belongs *P. infestans*, which produces the potato disease. The tissues of the host undergo decomposition in the infected parts and turn black: the mycelium of the Fungus extends from the circumference of these spots, and throws up hyphæ bearing sporangia through the stomata (Fig. 89). The zoospores developed in the sporangia of the parasite find their way to healthy plants: they also penetrate through the soil to the tubers, and the mycelium which is developed from them extends into the young potato-plant which grows from the tuber. No sexual reproductive organs have been observed in this Fungus as yet. *Phytophthora Fagi* infects and destroys the seedlings of the Beech. In Cystopus (*C. candidus* on Capsella and other Crucifers, *C. cubicus* on Compositæ) hyphæ bearing sporangia are formed in great numbers close together under the epidermis, and cause its rupture: each hypha bears a number of sporangia.

8. The ENTOMOPHTHOREÆ are parasitic upon Insects. *Empusa Muscæ*, for instance, infests house-flies more especially in the autumn. The sporangia are formed by abstriction from cells which protrude from the body of the fly. Within them spores are formed which are projected against the under-surface of the bodies of living flies, the only part at which penetration is possible. In other species resting-spores have been detected which are possibly of sexual origin.

9. The ASCOMYCETES have a mycelium consisting of multicellular hyphæ, on which a fructification is formed (ascertained with regard to some and hardly to be doubted with regard to the others) in consequence of fertilisation. The formation of the ascospores takes place within certain cells of the fructification called *asci*. Free cell-formation takes place within them, usually eight spores being

formed. Each of these surrounds itself with a proper cell-wall (Fig. 39); sometimes they undergo division. They are usually extruded from the asci. Fertilisation may take place in two ways. In the one, two contiguous branches of the mycelium become intimately connected: of these one, which is usually the larger, is the female organ, it is frequently spirally rolled, and is designated as the *ascogonium* (Fig. 90 *B* and *C as*); the other smaller one, which attaches itself to the ascogonium, is the male organ, the *pollinodium* (Fig. 90 *B* and *C p*). In the other way, the female branch of the mycelium is spirally wound and ends in a projecting filament quite similar to the trichogyne of the Florideæ (see page 120), to which the spermatia become attached. The *spermatia* are small cells,

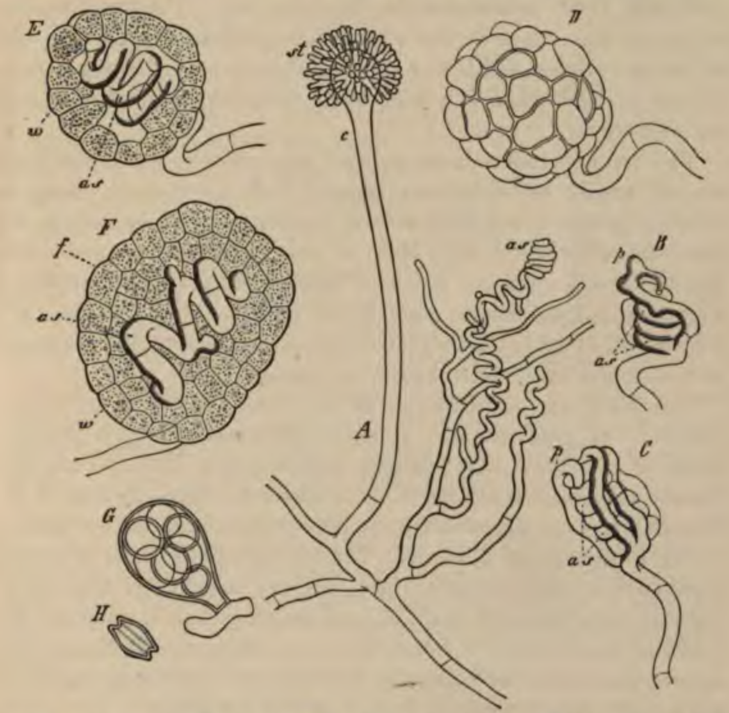


FIG. 90.—*Eurotium repens.* *A* A portion of the mycelium with hyphæ (*c*) bearing conidia: the conidia have already fallen off from the sterigmata (*st*); *as*, a young ascogonium *B* Ascogonium (*as*) with a pollinodium (*p*). *C* Another, with hyphæ growing up round it. *D* A fructification seen on the exterior. *E*, *F* Sections of unripe fructifications; *w* the investment; *f* filaments arising from the ascogonium, which subsequently bear the asci. *G* An ascus. *H* A ripe ascospore (magnified). (After Sachs.)

incapable of spontaneous motion, formed by abstriction in special receptacles known as the *spermogonia* (Fig. 99). This occurs in the Lichens. Whilst the fertilised ascogonium developes and finally produces the asci (which are often arranged in a special layer called the *hymenium*, in which they are mingled with sterile filaments, the *paraphyses*), the surrounding hyphæ grow to form an investment which wholly or partly encloses the product of fertilisation, and with these constitutes the fructification. The fructification either remains closed or has a very narrow opening, when it is said to be *angiocarpous*, and is termed a *perithecium;* or it opens so as to expose the asci, when it is said to be *gymnocarpous*, and is termed an *apothecium*.

The mycelium also bears asexual reproductive cells, which are termed *conidia* or *stylospores*, because they are formed singly or in rows by abstriction from certain branches of the mycelium the *sterigmata* (Fig. 90 *A*, *st*). Many of the commonest forms of mould are the conidia-bearing forms of Ascomycetes which bear sexual organs and fructification only under exceptional conditions. Besides these, in many Ascomycetes stylospores are formed by abstriction in special receptacles known as *pycnidia*.

The following classification of the Ascomycetes is only provisional. A great number of them, characterized by a peculiar mode of existence, were formerly regarded as a distinct class, and known as Lichens; these will be considered separately last of all. The Ascomycetes proper are commonly divided into four groups.

(*a*) *Erysipheæ*, or Mildews. The fructification, which is a perithecium, has no hymenium: the asci are distributed apparently without order in every direction, and are often few in number; the perithecium, the wall of which often has characteristic filamentous appendages, opens by irregular rupture, or in some cases not at all, so that the spores are only liberated by its decay.

Species of the genus Erysiphe and allied genera live on the surface of many plants, as the leaves of the Rose, the Hop, and others, and form a delicate white film known as mildew. The hyphæ of the mycelium throw out minute processes as suckers. The fructifications are visible to the naked eye as blackish specks. The conidia-bearing form of an Erysiphe of which the fructification is as yet unknown, which has been provisionally named *Oidium Tuckeri*, lives on the leaves and young fruit of the grape-vine, causing the well-known vine disease.

To this division belongs a not uncommon mould, *Eurotium Aspergillus* (Fig. 90): in this form the conidia are abstricted in rows on a spherical swelling of the fertile hypha which bears the sterigmata. The commonest mould is *Penicillium glaucum*, but it is doubtful whether it belongs to this group. It bears tufts of branched hyphæ, on which the conidia are formed in rows (Fig. 91). In this stage it occurs as a greenish grey film covering the substratum on which it grows, such as moist damp substances and fluids of all kinds. The fructification, only lately discovered, is as large as a pin's head and consists of a mass of pseudo-parenchymatous tissue which is traversed and absorbed by the ascogenous hyphæ with the exception of the most external layer which remains as a wall.

(*b*) The *Tuberaceæ*, or Truffles, have an underground, more or less spherical, completely closed perithecium, in which the hymenia bearing the asci line the surface of labyrinthine passages through the mass. The sexual organs and any other organs of reproduction are not known.

Tuber æstivum, *brumale*, and other species are eatable, and are known as Truffles; *Elaphomyces granulatus*, about the size of a walnut, is not rare.

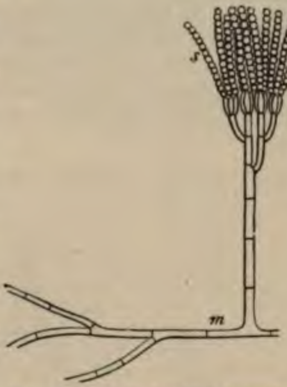


FIG. 91.—Fertile hypha of *Penicillium glaucum*. *s* The rows of conidia; *m* part of a hypha of the mycelium (× 150).

(*c*) *Pyrenomycetes*. The hymenium lines the inner surface of flask-shaped or spherical receptacles, the perithecia (Fig. 92 *C*, *cp*), which open at the apex. These perithecia occurs singly or in great numbers on a peculiarly constructed body, the *stroma*.

Among the simple forms with solitary perithecia must be mentioned the genera Sphæria and Sphærella, many species of which appear on dead leaves as black spots; Calosphæria, which forms its long slender perithecia in groups on the wood and bark of cherry-trees; Pleospora and Fumago, of which the mycelium and conidia constitute the black film known as Smut, which occurs on various parts of plants.

In the compound forms, those, that is, which have a stroma, the stroma forms warty incrustations or patches of irregular outline, which have a punctuated appearance owing to the numerous openings of the perithecia; *Diatrype disciformis*, which forms black warts as large as peas, belongs to this group, it is very common on dead boughs; also *Nectria cinnabarina*, which has a bright red stroma, and occurs on many kinds of dead wood; *Nectria ditissima* causes a disease on the branches of Beech-trees. In other cases the stroma developes into an upright club-shaped or branched tufted body, like the stromata of Xylaria, for instance, which occur very frequently on the trunks of trees; the conidia often appear as a mealy dust on the upper portion. *Claviceps purpurea*, known as Ergot, or officinally as *Secale cornutum*, also belongs here. The mycelium of this fungus covers the young ovaries of the Rye or other cereals which it attacks, and bears conidia which are imbedded in a mucilaginous substance, forming what is known as Honey-dew. By means of these, other plants may become infected. In course of time the fungus pervades the whole tissue of the ovary, and after it has destroyed it, it forms a hard mass of tissue of about 1-2 centimetres in length and of a dark violet hue, the *sclerotium*, which is known as Ergot. This sclerotium, after it has fallen to the ground, gives rise in the following year to a few stromata, which resemble little knobs borne on stalks (Fig. 92 *A*); and the perithecia, which are very numerous, are imbedded in the tissue at the surface (Fig. 92 *B*, *cp*). The ascospores which are developed in these find their way to young Rye plants, and their mycelium, penetrating through the leaf-sheaths, extends to the flower, where again the Honey-dew is formed. The various species of Cordyceps infect the larvæ of insects.

(*d*) The *Discomycetes* differ from the preceding only in that the hymenium covers the surface of the discoid or cup-shaped fructification which is an apothecium (Fig. 93 *h*).

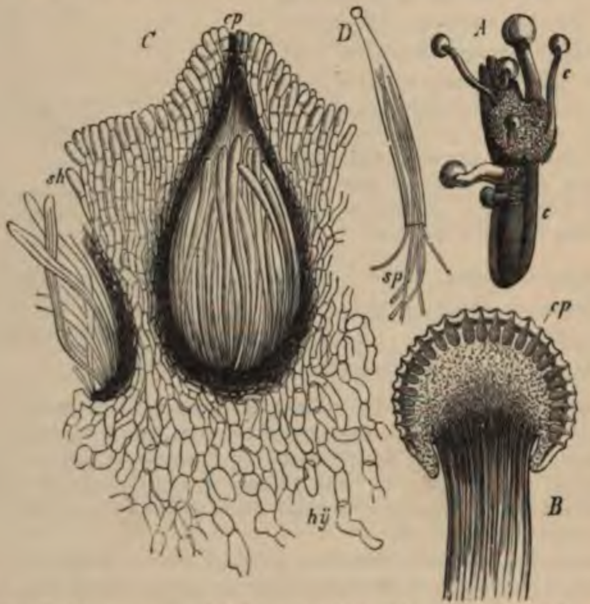


Fig. 92.—*Claviceps purpurea*. *A* A Sclerotium (c) (× 2) bearing stromata (*cl*). *B* Section of a stroma; *cp* the perithecia. *C* A perithecium more highly magnified. *D* An ascus ruptured, the elongated spores (*sp*) are escaping. (Sachs.)

1. The *Phacidiaceæ* grow upon various parts of plants, to which the small black fructification is closely attached. *Rhytisma Acerinum* appears in the form of round dark spots on the leaves of the Maple. The mycelium is probably parasitic, but the development of the fructification does not take place until after the leaves have fallen. The same is the case with *Hysterium nervisequium*, which inhabits the leaves of the Silver Fir, with *H. macrosporum*,

which inhabits those of the Spruce, and with *H. Pinastri*, which inhabits those of the Pine. They cause the leaves to turn brown and to fall off. The apothecia are somewhat elongated, and cause the rupture of the epidermis.

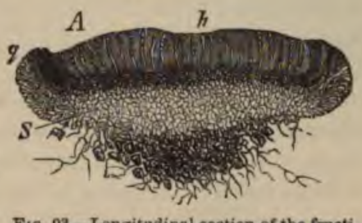


FIG. 93.—Longitudinal section of the fructification of *Peziza convexula*; *h* the hymenium. (After Sachs.)

2. The *Pezizaceæ* have fleshy or waxy cup-shaped apothecia. They grow upon different substrata, Ascobolus upon dung, some species of Peziza upon earth, others upon parts of plants (*P. Willkommi* causes the so-called cancer of the stems of the Larch). Bulgaria, with a gelatinous orbicular fructification, upon dead branches.

3. The *Helvellaceæ* have usually club-shaped apothecia, the smooth or reticulate surface of which is covered by the hymenium. To this group belong the (esculent) species of the genus Morchella, the Morell, Helvella, etc.

The *Lichens* were formerly regarded as a distinct class; but recent investigations have shown that they are Ascomycetes belonging to the Pyrenomycetes and Discomycetes which are parasitic on Algæ. These Algæ are enclosed in the thallus of the Lichen, and were formerly termed *gonidia* (Fig. 94 *g*). The gonidia are either solitary spherical green cells belonging to the Palmellaceæ (Algæ), or they are cellular filaments: if they are of a red colour they belong to the genus Chroolepus, if of a bluish-green they belong to the genus Nostoc or to some other genus of the Phycochromaceæ. They may be either irregularly distributed throughout the thallus, when it is said to be *homoiomerous*; or they may be arranged in definite layers in the

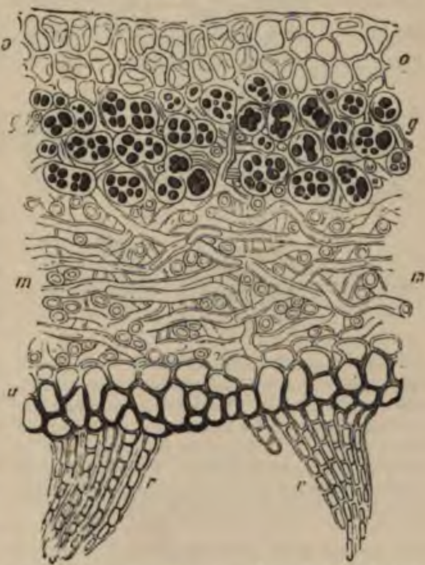


FIG. 94.—Transverse section of the thallus of *Sticta fuliginosa* (× 500). *o* Cortex of the upper surface; *u* under surface; *m* network of hyphæ forming the medullary layer; *g* gonidia; *r* root-like outgrowths (rhizines) of the under surface. (After Sachs.)

mycelium, when the thallus is said to be *heteromerous* (Fig. 94). The organs of reproduction belong entirely to the Fungus, and the carpospores are produced in asci. The asci in some cases are contained in apothecia (in the Discomycetes); in others they are enclosed in perithecia (Pyrenomycetes) (Gymnocarpous and Angiocarpous Lichens). In these, as in other Ascomycetes, spermogonia occur: in the Lichens they are receptacles, probably to be regarded as male organs, in which spermatia are formed by abstriction. The female organ, which is termed a carpogonium, is a hypha which forms two or more coils of short cells in the thallus, and then proceeds straight to the surface, beyond which the terminal cell projects; the coiled part is termed the ascogonium, the straight part is termed the trichogyne. It resembles the female organ of the Florideæ in that it is multicellular, and the same term is made use of in the two cases. The spermatia are brought by means of water into contact with the trichogyne, and the contents of one or more spermatia pass into it. The result of this fertilisation is the development of an apothecium, the asci of which are alone developed from the ascogonium, whereas the rest of the apothecium is formed by a special development of other hyphæ lying around it. The trichogyne takes no part in the formation of the fructification. Lichens are also reproduced by means of *soredia*: these are small groups of gonidia invested by hyphæ, which are set free from the thallus and grow into a new individual (Fig. 95).

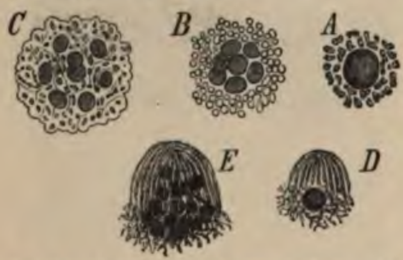


FIG. 95.—*A–D* Soredia of *Usnea barbata*. *A* A simple soredium, consisting of a gonidium covered with a web of hyphæ. *B* A soredium, in which the gonidium has multiplied by division. *C* A group of simple soredia, resulting from the penetration of the hyphæ between the gonidia. *D, E* Germinating soredia; the hyphæ are forming an apex of growth, and the gonidia are multiplying. (After Sachs.)

Lichens grow on trees, rocks, walls, and on the earth amongst Mosses: they may become completely dried up without having their vitality destroyed.

According to the form and texture of the thallus, Lichens may be arranged in the four following groups.

(*a*) *Fruticose Lichens.* The thallus grows erect in a shrub-like manner: its internal structure is the same in all parts; that is, there is no distinction of an upper and an under surface: the gonidial layer usually forms a hollow cylinder.

To this group belong the various species of Usnea (Fig. 96 *A*), and allied genera with a cylindrical thallus, which grow on trees. *Roccella tinctoria* grows on rocks in regions bordering on the Mediterranean; from it and other allied Lichens litmus is prepared. Ramalina and Evernia, with a ribbon-shaped flattened thallus, occur on trees and wooden fences; *Cetraria islandica* is the Iceland Moss, which forms a mucilaginous fluid when boiled with water. *Anaptychia ciliaris*, which resembles the foliaceous Lichens, with a flattened thallus, is common on the trunks of trees. Cladonia has a scaly decumbent thallus, from which erect branches spring bearing the apothecia: *Cladonia fimbriata* is common; *Cladonia rangiferina*, the Rein-deer Moss, occurs on moors: Sphærophorus has the same external appearance, but it is pyrenocarpous.

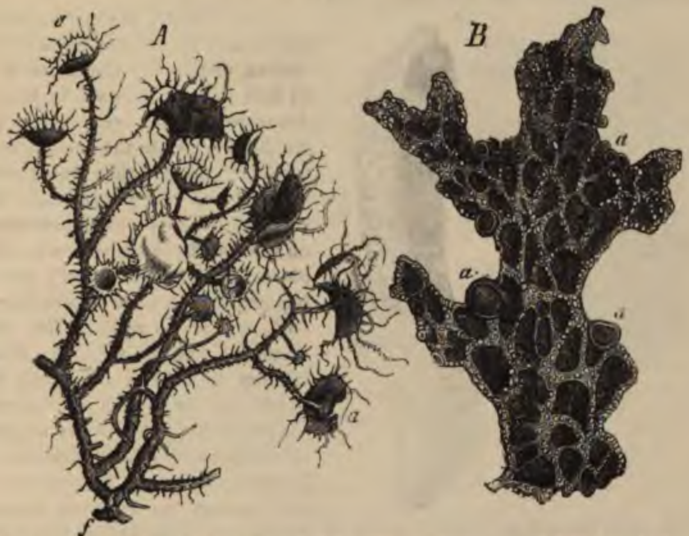


FIG. 96.—*A* A fruticose Lichen, *Usnea barbata*, with apothecia, *a*. *B* A foliaceous Lichen, *Sticta pulmonacea*, with apothecia, *a* (nat. size). (After Sachs.)

(*b*) *Foliaceous Lichens*. The thallus is flattened and adheres to the substratum: the green (rarely bluish-green) gonidia form a single layer beneath the upper surface (Fig. 94). The margin of the thallus is usually lobed.

Parmelia parietina occurs, with its bright yellow thallus, bearing apothecia, on tree-trunks and walls, together with other species of a grey colour. *Sticta pulmonacea* (Fig. 96 *B*), has a reticulated yellowish thallus, and grows on tree-trunks. Peltigera is represented by several species which grow on mossy banks in woods: the apothecia are borne on the margin of the lobes of the thallus.

Umbilicaria and Gyrophora, of a dark colour, grow on silicious rocks. Endocarpon has a grey thallus with numerous small perithecia, which appear as black dots: it grows on rocks.

(*c*) *Crustaceous Lichens.* The thallus is usually indefinite in outline, and can often be scarcely distinguished from the substratum, the fructification alone being conspicuous.

The numerous species and genera are classified according to the size and form of the spores and to the structure of the fructification.

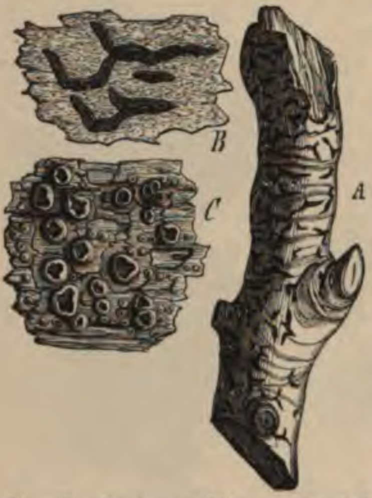


Fig. 97. — Crustaceous Lichens. *A* and *B* *Graphis elegans*. *B* Slightly magnified. *C* *Pertusaria Wulfeni*, slightly magnified. (After Sachs.)

(*a*) *Discocarpi:* the apothecium is surrounded by an outgrowth of the thallus, and in the Lecanoreæ it is at first entirely enclosed by it, *e.g.*, *Lecanora subfusca*, common on the trunks of trees: in the Lecideaceæ it is surrounded by a ridge, but is never enclosed; to this group belong the common *Buellia parasema*, occurring on tree-trunks, *Rhizocarpon geographicum*, which forms bright yellow incrustations of often enormous extent on silicious rocks. The apothecia are irregular, sometimes linear in form (Fig. 97 *A B*) among the Graphideæ, the gonidia of which are the red cells of Chroolepus: *Graphis scripta* is common on the trunks of Beeches. The small Caliciеæ, which are common on bark, on wooden fences, etc., have stalked apothecia, as also the Bæomyceæ (without any ridge): *Bæomyces roseus* is common on sandy soil.

(*b*) *Pyrenocarpi.* The perithecia are imbedded in outgrowths of the thallus, either singly or several together, as (Fig. 97 *C*) in Pertusaria: they project from the thallus, and are provided with a special black investment in the Verrucarieæ.

Many species of crustaceous Lichens inhabit the highest peaks of the Alps, on which no other vegetation is to be seen, and they contribute materially to the weathering of the rocks. When they grow on the trunks of trees, they occur more especially upon those which have a smooth surface: the formation of bark interferes with their growth.

(*d*) *Homoiomerous Lichens.* The gonidia belong to the Phycochromaceæ: the thallus is usually lobed, of a dark colour, more or less gelatinous, sometimes filamentous.

The latter is the case in Ephebe, which consists essentially of a filamentous

Alga (Sirosiphon) surrounded by hyphæ. Collema is gelatinous (Fig. 98); it grows on moist earth and on rocks.

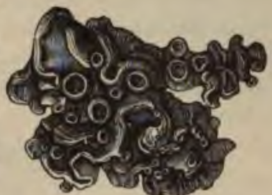


FIG. 98.—A gelatinous Lichen, *Collema pulposum*, slightly magnified. (After Sachs.)

10. The USTILAGINEÆ are parasitic in the tissues of the higher plants. Their spores are formed from the protoplasmic contents of cells of the hyphæ, the walls of which become mucilaginous, and are usually of a black colour. These cells occur in great numbers in those parts of the host, usually the reproductive organs, which are permeated by the mycelium. Several species infest our Cereals, and the seeds become filled with spores. The spores germinate at the same time as the sound seeds, producing a promycelium which bears small cells, *sporidia;* when these germinate their mycelium penetrates the young plants and extends into the flowers, where a fresh formation of spores takes place.

The most important and the most common species are *Ustilago Carbo*, which especially attacks Oats, but other Cereals and Grasses as well: *U. Maidis*, which produces large tumours in the Maize, filled with spores; *Urocystis occulta*, which fructifies in the leaves and haulms of the Rye: *Tilletia caries*, the smut of Wheat; this is dangerous because the grains filled with spores remain closed, and are therefore harvested with the sound ones. Many other species and genera infest wild plants.

11. The UREDINEÆ, or *Rusts*, are also parasites: their mycelium inhabits the cells of various kinds of plants and usually bears several kinds of reproductive cells. In most of them small fructifications, termed *æcidia*, are borne by the mycelium, formed probably in consequence of the fertilisation of female organs by spermatia (Fig. 99 *I. a* and *A*). They project from the surface of the infested plant as small cups; the interior is covered towards the base by a layer of basidia, on each of which there is a row of *æcidiospores*, generally of a red colour, which have been formed by abstriction: the investment of the fructification is formed by the peripheral rows of æcidiospores, which are sterile and which have become coherent. Besides these æcidia, and generally associated with them, are found the spermogonia (Fig. 99 *I sp*) in which the spermatia are developed; in addition to these—but generally at a different season of the year—two other forms of reproductive cells occur, which are abstricted from their basidia singly and not in rows, and the basidia bearing them do not form a definite hymenial

layer, but irregular groups, which break through the epidermis of the host. These cells, which correspond to the conidia of other Fungi, are, firstly, the *uredospores*, or "summer-spores" (formerly regarded as a distinct genus and called Uredo (Fig. 99 *III ur*); they are always one-celled, usually of a red colour, and they germinate without any period of quiescence, by the protrusion of an ordinary

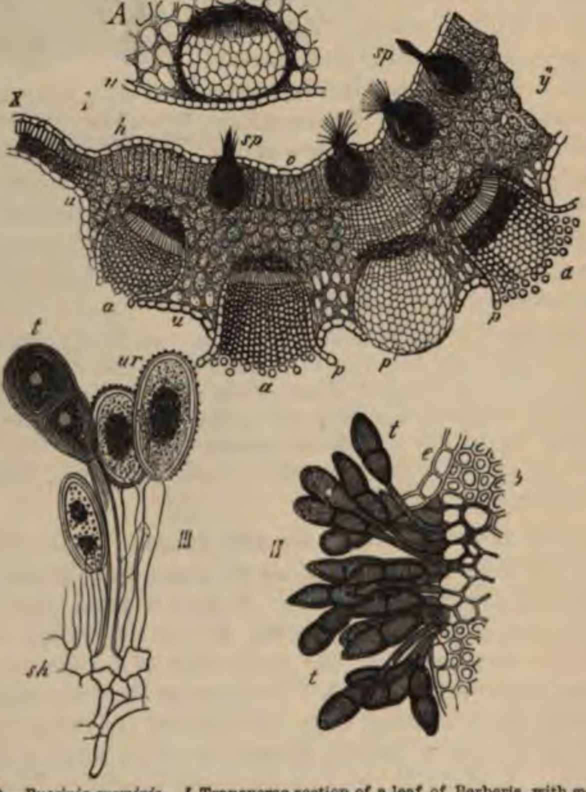


FIG. 99.—*Puccinia graminis.* *I* Transverse section of a leaf of Berberis, with æcidia (*a*); *p* the wall of the æcidia; *u* lower, *o* upper surface of the leaf, which has become thickened at *u y* in consequence of the presence of the parasite; on the upper surface are spermogonia (*sp*). *A* A young æcidium which has not yet burst. *II* Layer of teleutospores (*t*) on the leaf of *Triticum repens*; *e* its epidermis. *III* Part of a layer of uredospores on the same plant; *ur* the uredospores; *t* a teleutospore. (After Sachs.)

mycelial hypha: by means of these the parasite is conveyed to other individuals, on which in a few days it produces fresh uredospores. Secondly, there are the *teleutospores*, or "winter-spores," which are mostly black and often many-celled (Fig. 99 *III t* and *II*);

they are formed in many species only in the autumn, and persist during the winter, germinating subsequently in a peculiar manner. The hypha produced from the spore, the *promycelium*, divides into four cells, from each of which a minute cell, called a *sporidium*, is abstricted, which finds its way to a host. These various forms of reproductive cells usually alternate; thus the mycelium developed from the æcidiospores produces uredospores, and the mycelium that proceeds from these (often after several uredospore-bearing generations have intervened) produces teleutospores; from these sporidia are developed, which, when they germinate, give rise to a mycelium producing æcidia. In many species *heterœcism* takes place; that is, that this variety of form of the reproductive cells is connected with a change of hosts. All species, however, have not so great a variety of spore-forms. Some Uredineæ are known in which the æcidiospores produce æcidia, and others in which the teleutospores produce a mycelium bearing teleutospores. In other cases there are grounds for assuming that their life-history is at present but imperfectly known. They fall into the following natural subdivisions:

(*a*) *Puccinieæ.* The teleutospores are one or more-celled on solitary free stalks; æcidia and uredospores are also commonly found. To the genus Puccinia, with a two-celled teleutospore, belongs *Puccinia graminis* (Fig. 99), the Rust of Wheat; the uredospores (formerly called *Uredo linearis*) form red streaks on the leaves and haulms of cereals and grasses; in the autumn the teleutospores appear in similar streaks, but they are black; these germinate in the following spring exclusively on the leaves of Berberis where the æcidia appear in red swollen patches (formerly known as *Æcidium Berberidis*); the æcidiospores are conveyed to Grasses, and there give rise to a mycelium with uredospores, the Rust. The same processes take place in *P. straminis*, the æcidia of which are formed on Borages; and *P. coronata*, the æcidia of which are formed on Rhamnus. These three forms of Rust cannot grow on Grasses unless their æcidia have been previously produced in the spring; hence their appearance depends on the presence of plants which are suitable for the development of the æcidia. Of *P. Malvacearum*, only the teleutospores are known; they are constantly reproduced from the mycelium which they form, so that no alternation occurs. *P. Compositarum* has all these different kinds of spores, and produces them on the same host. Uromyces differs from Puccinia only in having one-celled teleutospores; *U. Betæ* is the Rust which grows on the Beetroot:—to this genus the æcidium may probably be referred which is formed in the leaves of *Euphorbia Cyparissias* (probably to *U. Pisi*, the rust of the Papilionaceæ, or to *U. scutellatus*, that of the Euphorbiæ), and causes a conspicuous enlargement of them. The æcidium-mycelium is perennial in the rhizome of the Spurge. Phragmidium, with many-celled teleutospores, is common on the leaves of the Rose, Blackberry, and others.

(*b*) *Gymnosporangieæ.* The teleutospores are two-celled, on stalks which are united into a gelatinous mass; the mycelium which bears them is perennial in the branches of some Coniferæ, particularly the species of Juniper; teleutospores are formed in the spring and germinate on the leaves of Pomaceæ, on which the large æcidia, which open in a peculiar manner, are found in summer. *Gymnosporangium fuscum* occurs on *Juniperus Sabina*, the æcidia (known as *Ræstelia cancellata*) on the leaves of Pears: *G. clavariæforme* on *Juniperus communis*, the æcidia (*Ræstelia lacerata* and *penicillata*) on the leaves of Apples and Hawthorns: *G. conicum* also on *J. communis*, and the æcidia (*R. cornuta*) on the Mountain Ash.

(*c*) *Melampsoreæ*. The teleutospores are many-celled, and are united together into a firm palisade-like layer; the æcidia are for the most part unknown, but the uredospores of many forms have been found. Melampsora has black layers of teleutospores; *M. salicina*, *populini*, *Lini*, attack the plants whose names they bear. *Calyptospora Göppertiana* occasions conspicuous swellings on the stems of *Vaccinium Vitis Idæa*. *Chrysomyxa Abietis*, with gold-coloured teleutospores, appears at the end of April on the second year's leaves of Spruces, and, as they germinate, they infect the young leaves. Coleosporium, likewise with gold-coloured teleutospores, grows on many herbaceous plants. *Æcidium Pini* forms a perennial mycelium in the leaves and bark of Pine-trees, and bears in the spring its æcidia, which have a white investment; it belongs to *Coleosporium Senecionis*, a common species, which bears uredospores in the summer and teleutospores in the autumn on *Senecio sylvaticus*. The innoculation of Pines can only be effected by means of the teleutospores formed on Senecio.

(*d*) The *Endophylleæ* bear only æcidia which reproduce themselves without the intervention of any other form of spore. *Endophyllum Sempervivi* grows on the leaves of the House-leek.

(*e*) *Imperfectly-known Æcidia*, which do not directly reproduce themselves, and must therefore possess teleutospores: the relations of these are not as yet known. To these belong *Æcidium elatinum*, which inhabits the cortex of the Silver Fir, and causes large crab-like excrescences, as well as the monstrous growth of twigs, known as "Witches-brooms," on the leaves of which the æcidia appear. *Æc. Abietinum* occurs on the leaves of the Spruce in mountainous districts. *Æc. strobilinum*, on the scales of Spruce-cones. Cæoma is also regarded as an æcidium; the hymenial layer is not enclosed by any investment. *C. pinitorquum* grows on the branches of young Pines, often on one side only, so that they become bent.

12. Basidiomycetes. To this group belong most of the larger Fungi commonly known as Mushrooms and Toadstools. The mycelium consists of delicate white strands of hyphæ, which pervade the substratum upon which it grows, and the part which is usually recognised as the Fungus is the fructification, that is, the organ which produces the conidia. It was formerly thought that this fructification was formed, as in the Ascomycetes, as the result of a process of fertilisation taking place in the mycelium; but most careful investigation has failed to detect any trace of a sexual process; the fructification is simply formed by the outgrowth of

certain parts of the mycelium. In view of the high organization of these Fungi, it may be reasonably assumed that sexuality has here gradually disappeared.

The conidia are formed in or upon the fructification on basidia, which together form the hymenium; the basidium (Fig. 100 *C*) usually bears at its summit four small, slender sterigmata, from each of which a conidium is abstricted.

(*a*) The *Tremellineæ*, or gelatinous Fungi, have basidia resembling in form the promycelium of the Uredineæ. The fructification is soft and mucilaginous; its surface is covered by the hymenium which, at the time of the formation of the conidia, looks as though powdered with white dust.

Tremella mesenterica, with irregularly furrowed fructification; ***Exidia Auricula Judæ***, a spongy Fungus growing on the Elder, with a brownish fructification somewhat resembling the shell of an ear, and others, are not rare on rotten wood.

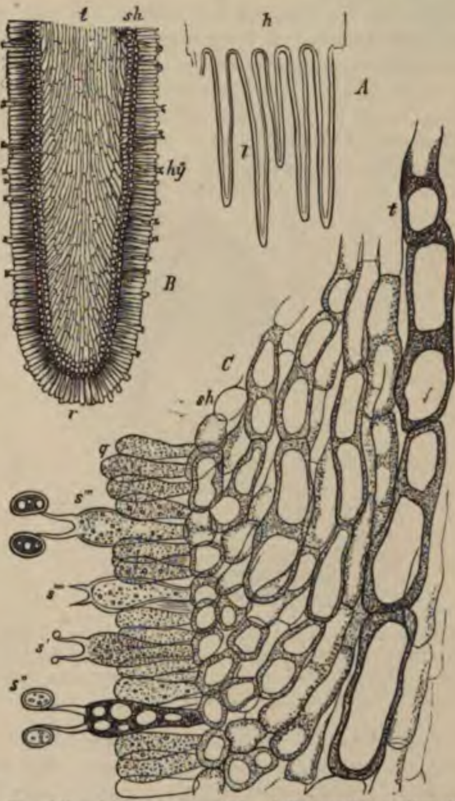


FIG. 100.—*Agaricus campestris*. *A* Tangential section of the pileus, showing the lamellæ, *l*. *B* A similar section of a lamella more highly magnified; *hy* the hymenium; *t* the central tissue called the Trama. *C* A portion of the same section more highly magnified (× 550); *q* young basidia and paraphyses; *s'* the first formation of conidia on a basidium; *s''* more advanced stages; at *s''''* the conidia have fallen off. (After Sachs.)

(*b*) *Hymenomycetes*. The structure of the basidia is similar to that above described; the fructification bears the hymenium on its upper surface, which is very various in form; the very numerous forms are accordingly subdivided into:

1. *Thelephoreæ;* the surface bearing the hymenium is extended over the substratum as a crust, or else forms the smooth under-surface of a hat-shaped fructification. The simplest form is *Exobasidium Vaccinii*, which is parasitic on the leaves of the Red Whortleberry, and very commonly covers them with a whitish crust. Corticium forms crusts on the bark of trees; Stereum has a hat-shaped fructification which, when seen from above, bears some resemblance to various species of Polyporus, but it has a smooth hymenial surface; it is common on trunks of trees, palings, etc.

2. *Clavarieæ.* The hymenium clothes the smooth surface of the fructification, which is cylindrical, or club-shaped, and often branched. The genus Clavaria has many species; *C. flava* has a sulphur-yellow, coral-like fructification which is edible (Fig. 101 *A*).

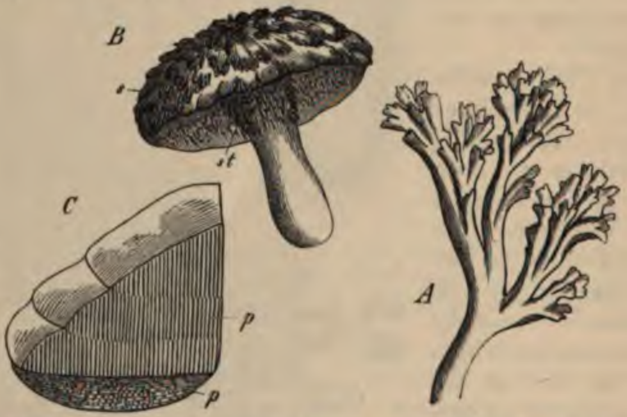


FIG. 101.—*A* Branch of *Clavaria flava* (nat. size). *B* Fructification of *Hydnum imbricatum*; *st* prickles; *s* scales of the upper surface (½ nat. size). *C* Longitudinal section through the fructification of a Polyporus; *p* the tubes clothed with the hymenium; the tubes show on the under surface as pores (½ nat. size).

3. *Hydneæ.* The hymenium covers prickly projections of the fructification, which is either a crust or is hat-shaped, and is either attached laterally or stalked. *Hydnum imbricatum* is eatable: other species have a fleshy pileus with a central stipe (Fig. 101 *B*).

4. *Polyporeæ.* The hymenium clothes the inner surface of tubes, which are either free or, more often, connected into a layer which covers a portion of the fructification. The fructification of Polyporus and Trametes is generally attached laterally, and often of a horse-shoe shape (Fig. 101 *C*). *P. fomentarius* is used in the preparation of what is known in England as German tinder; *P. officinalis* is used in medicine as *Fungus Laricis;* the mycelium of *Trametes Pini* attacks the heart-wood of Pines and makes them decay; *T. radiciperda* occurs in the roots and lower part of the trunk of Spruces and Pines, causing their destruction. Dædalea occurs on old oaks; its tubes anastomose and form a labyrinth. The mycelium of *Merulius lacrimans* penetrates the timbers of houses and causes them to decay (Dry Rot). Boletus has a fleshy stalked pileus,

from which the hymenial layer may be easily separated. *Boletus edulis* and *scaber* are edible; *B. Satanas* and others are poisonous.

5. *Agaricinæ.* The hymenium clothes special lamelliform outgrowths of the fructification, which commonly assumes the form of a stalked or sessile pileus. The stalked forms are either naked from the first, or they are enclosed at an early stage in an investment which remains after the full development of the fructification as an appendage of one form or another. An investment which at first surrounds the whole pileus and stipe, and, at maturity, surrounds the base of the stipe like a sheath, as in Amanita, is called a *velum universale* (Fig. 102 *A B v*): while a *velum partiale* only covers the under surface of the pileus where the lamellæ are borne, and when this is fully developed it is represented only by fragments hanging from the margin or forming a ring round the stipe (Fig. 102 *C a*), *e.g.*, *Agaricus campestris* and *procerus*: in the Fly-toad-stool, *Amanita muscarius*, both kinds of velum are present together. Besides these conspicuous characters the colour of the conidia is also of importance for distinguishing the species; this is easily discovered by laying the fructification on white or black paper, which becomes covered with the conidia which fall out very readily.

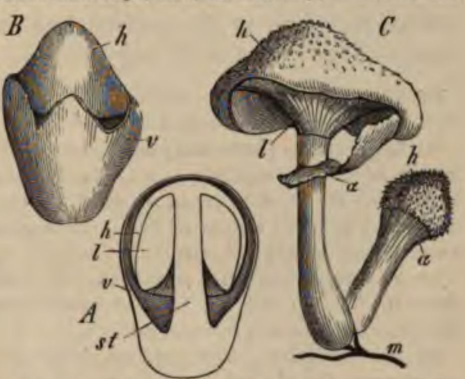


FIG. 102.—*A* Early stage in the development of the fructification of *Agaricus vaginatus*: *v* the velum universale; *st* the stipe; *h* the pileus; *l* the lamellæ. *B* A somewhat later stage; *v* the ruptured velum. *C Agaricus melleus*: *m* the mycelium; *a* the ring formed by the velum partiale (⅓ nat. size).

The great genus Agaricus (the lamellated Fungi) has lately been subdivided into several genera. In Coprinus the fructification very soon undergoes disintegration, forming a black shiny fluid; Lactarius contains milky juice (latex). In Cantharellus the lamellæ are prolonged down the stipe. Of edible species the following may be named: *Cantharellus cibarius*, *Lactarius deliciosus*, *Agaricus campestris*, the Mushroom, *A. procerus*, distinguished by a moveable ring, and *A. Cæsareus*: the poisonous species are *Lactarius torminosus* and *Agaricus* or *Amanita muscarius*. *A. melleus* has a peculiar mycelium, matted into strong shining black cords, formerly regarded as the genus Rhizomorpha, which lives in the bark of trees and kills young Conifers, particularly Spruces and Pines; it gives off subterranean branches which attack the roots.

The fructification of other species is of a hard leathery or woody consistency; these live commonly on old wood; such are Panus, with a small pileus mounted on an eccentric stipe; Lenzites, where the pileus is lateral and sessile; Marasmius, the elegant pilei of which are often seen on the leaves of Conifers which have fallen off.

(*c*) *Gastromycetes.* In these, as the name suggests, the hymenium is enclosed within the fructification, the internal tissue of which forms numerous cavities or chambers, the dividing walls being known as the *trama;* the hymenium clothes these cavities, being attached to the trama. When the fructification is ripe, great changes commonly take place in this internal tissue, which have as their object the dispersion of the conidia; the external wall (*peridium*) usually consists of two layers. This group is subdivided as follows, according to the modifications undergone by the internal tissue and the character of the peridium.

(*a*) *The Hymenogastreæ*, in which the chambers and hymenium are persistent; these are truffle-like underground Fungi.

(*b*) *Lycoperdaceæ* (Puff-balls); only a few strong threads of the internal trama remain, forming the *capillitium*, with the isolated conidia between them. In Lycoperdon the outer peridium scales off, the inner splits open at the top, and the conidia escape as a cloud of dust. In Geaster the outer peridium splits in a star-shaped manner and rolls back; the inner opens by a hole at the summit.

(*c*) *The Nidularieæ* have a vase-shaped fructification within which the chambers become isolated, forming small hard bodies. Crucibulum and Cyathus are not rare on rotten wood.

(*d*) *The Phalloideæ*. The peridium consists of three layers, and after they are ruptured the whole internal tissue is elevated on a stalk and becomes an ill-smelling mucilaginous mass containing the conidia. *Phallus impudicus* is poisonous and occurs among brushwood.

GROUP II.

MUSCINEÆ.

In this group we find a sharply defined alternation of generations which, in certain points, agrees with that of the following group; a sexual generation—that is, one which produces sexual organs—alternates with an asexual generation, which produces only spores. The germinating spore gives rise to the sexual generation (the oophore), the Moss-plant, in some cases directly, but in most cases after the formation of a filamentous growth, the *protonema*. In the lower forms this generation is a thallus, but in the higher it consists of stem and leaves, and is capable of repeatedly developing sexual organs. From each oosphere an individual of the asexual generation (the sporophore) is developed, which continues to be superficially connected with the original Moss-plant, and assumes the form of a stalked capsule which is commonly known as the fruit of the Moss; this body forms spores, without any ramification or repetition, and its vital activity ceases with the ripening of the spores.

Since Mosses have a distinct stem and leaves, but no true roots nor vascular tissue, they take the lowest rank among the Cormophytes.

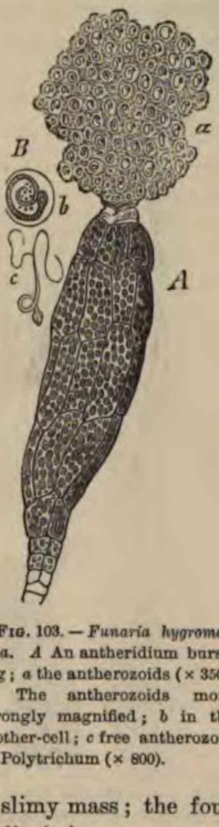


FIG. 103.—*Funaria hygrometrica*. *A* An antheridium bursting; *a* the antherozoids (× 350). *B* The antherozoids more strongly magnified; *b* in the mother-cell; *c* free antherozoid of Polytrichum (× 800).

The male organs, as in all the higher Cryptogams, are called *Antheridia*, the female, *Archegonia*.

The *antheridia* are spherical, ovate, or club-shaped bodies, with long or short stalks (Fig. 103); the external layer of cells forms the wall, while in each of the internal cells, which are small and very numerous, an antherozoid is developed. The wall ruptures at its apex when it is moistened, and the mother-cells of the antherozoids are set free; they subsequently discharge their contents. The antherozoids (Fig. 103 *c*) are spirally-wound filaments thickened posteriorly; the anterior end is furnished with two delicate cilia by which they move in the water usually present in the capillary spaces between the leaves of Mosses.

The *archegonia* (Fig. 104) are flask-shaped bodies, dilated at the base and terminating upwards in a long neck. An axial row of cells is contained in each archegonium; the lowest cell, which is the largest, is the *oosphere*, and the remainder are *canal-cells:* the latter are disintegrated shortly before fertilisation, so as to form a slimy mass; the four uppermost cells of the neck, the stigmatic cells (*m*), separate, and the antherozoids pass through the opening into the canal and reach the oosphere, which becomes surrounded by a membrane as a consequence of fertilisation.

The sexual organs are often solitary, but are also frequently collected into groups which sometimes consist exclusively of archegonia or of antheridia, but sometimes of both. These groups, known sometimes as Moss-flowers, are occasionally surrounded by special investments, the *perichætium* and the *perigynium*, consisting of modified leaves. The hair-like organs which occur at the insertion of the sexual organs in these so-called flowers are the *para-*

physes. The second or spore-forming generation (sporophore), the *sporogonium*, is immediately developed from the fertilised oosphere. The base of the sporogonium penetrates more or less into the tissue of the Moss-plant, and is even nourished by it, but the cells of the two generations are not in organic connection with each other. The wall of the archegonium, within which the development of the oospore into the sporogonium proceeds, continues to grow for some time, and surrounds the young sporogonium, when it is called the *calyptra* (Fig. 105 *c h*). At a later stage it is

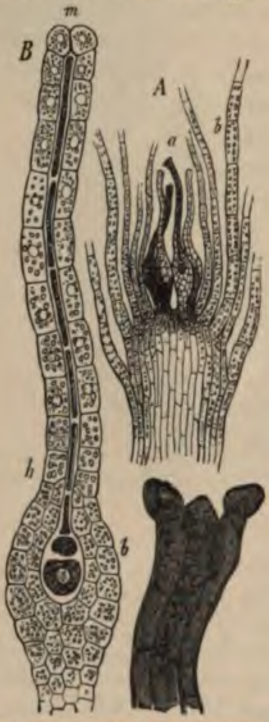


FIG. 104.—*Funaria hygrometrica.* *A* Longitudinal section of the summit of a weak female plant (×100); *a* archegonia; *b* leaves. *B* An archegonium (× 550); *b* ventral portion with the oosphere; *h* neck; *m* mouth still closed; the cells of the axial row are beginning to be converted into mucilage. *C* The part near the mouth of the neck of a fertilised archegonium with dark red cell-walls. (After Sachs.)

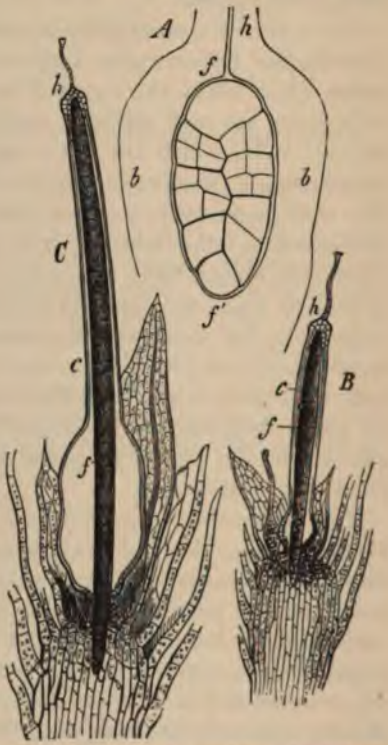


FIG. 105.—*Funaria hygrometrica.* *A* Origin of the sporogonium (*f f*) in the ventral portion (*b b*) of the archegonium (longitudinal section × 500). *B C* Different further stages of development of the sporogonium (*f*) and of the calyptra (*c*); *h* neck of the archegonium (× about 40).

ruptured in different ways according to the family to which the plant belongs, and the remains cling to the base or to the apex of the sporogonium.

The sporogonium assumes, sooner or later, the form of a capsule with a more or less elongated stalk (*seta*). Certain layers of tissue within the capsule give rise to the spores, by division of their cells into four. In the true Mosses and in the Anthoceroteæ, a central mass of tissue is left which does not give rise to spores, and is called the *columella*. On the other hand, in many of the Liverworts, some cells of the spore-forming tissue do not give rise to spores, but form the *elaters*, which are cells usually having a spiral thickening on their inner surface. The spores are in many cases set free by the decay of the wall of the capsule, but in general the capsule splits open, either in segments from the apex to the base, or irregularly, or the upper part of the capsule comes off like a lid (*operculum*); in most of the true Mosses there is an operculum which, from the first, is differently constructed to the rest of the capsule.

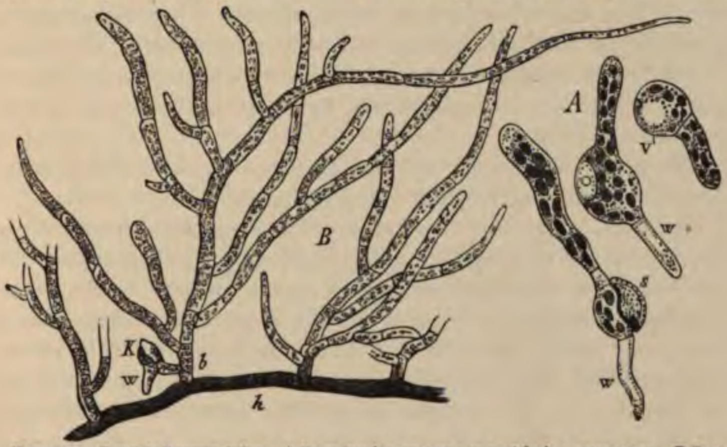


FIG. 106.—*Funaria hygrometrica*. *A* Germinating spores; *w* root-hair; *s* exospore. *B* Part of a developed protonema, about three weeks after germinating; *h* a procumbent primary shoot with brown wall and oblique septa, out of which arise the ascending branches with limited growth. *K* Rudiment of a leaf-bearing axis with root-hair (*w*). (*A* × 550, *B* about 90.)

The spores are spherical or tetrahedral; their cell-wall consists —as also in the following groups—of two layers: an outer and tougher one, the *exospore*, and an inner and more delicate one, the *endospore*. On germination, the outer layer splits open, and the cell, surrounded by the endospore, grows and divides, a process which in most cases leads to the formation of the protonema, which is either a network composed of filaments of cells containing chlorophyll, or else a flat, green, cellular body. The rows of cells forming the protonema are lateral appendages, which are either limited (Fig. 106 *B b*) or unlimited (Fig. 106 *B h*) in their growth; it is thus the simplest form of the Moss-plant. This is most conspicuous in the cases where it passes directly at its apex into a Moss-plant. More frequently this transition takes place by means of lateral buds (Fig. 106 *B K*) which arise at the base of a limited lateral branch.

The branching of Mosses is never axillary; the lateral shoots usually arise by the side of or below the leaves.

Many of the Mosses have organs for vegetative propagation, commonly known as *bulbils* or *gemmæ*, and besides these special organs they are in the highest degree capable of vegetative multiplication by simple branching and innovation; indeed, the forms which are of most frequent and extensive occurrence, *e.g.*, *Hylocomium triquetrum*, increase chiefly by these methods and rarely produce sporogonia.

The group is naturally divided into two classes which are distinguished principally by the following characters:—

Class III. *Hepaticæ* (*Liverworts*). The capsules never open by the separation of a special operculum; they are either four- or two-valved, or they open irregularly by the rupture of the upper portion, or they do not open at all. In most of the orders elaters are found among the spores; a columella is present only in the Anthoceroteæ; the spores ripen whilst the capsule is still enclosed in the calyptra. The calyptra clings, after its rupture, to the base of the capsule: the plant of the first generation is a thallus, or a stem furnished with leaves, the leaves being formed of only a single layer of cells; the stem is always bilateral; the root-hairs are unicellular.

Class IV. *Musci* (*True Mosses*). The capsule usually opens by a distinct operculum; elaters are never present, but the columella always, at least in the early stages. The calyptra is usually ruptured by the capsule long before the spores are ripe, and is elevated upon it. The plant of the first generation is a stem furnished with leaves which not unfrequently have a midrib of several layers of cells; the stem is not usually bilateral; the root-hairs are multicellular.

CLASS III.—HEPATICÆ (LIVERWORTS).

The capsule usually splits into four valves; elaters with spiral thickening are almost always present, but there is usually no columella; the calyptra remains attached at the base of the capsule.

The plant of the first generation, in some of the forms belonging to this class, is actually a leafless thallus; in others it is a thalloid stem, furnished with small scale-like leaves; others again have a stem bearing green leaves. The first two are said to be *frondose*, the last *foliose*. The frondose species cling closely to the surface on which they grow, and are consequently bilateral, the two sides or surfaces differing considerably; the cells of the upper surface contain much chlorophyll and are generally protected by a distinct epidermis, those of the under surface contain but little chlorophyll and alone give rise to root-hairs. The foliose forms also frequently creep over the substratum and exhibit various forms and arrangements of their leaves corresponding to their mode of life. In correlation with the bilateral structure which obtains throughout the whole class, the leaves are of two kinds; *inferior leaves*, which are inserted upon the side of the stem which is in contact with the substratum, and which are imperfectly developed; these are the only leaves borne by the frondose Liverworts which have any: in addition to these leaves (called in the foliose forms *amphigastria*) the foliose Liverworts have two rows of *lateral leaves*, which are inserted upon each side of the upper surface of the stem.

This class includes four orders.

Order 1. RICCIEÆ.

The archegonia and antheridia stand isolated on the upper side of the thalloid stem. The capsule is spherical, usually sessile; it contains no elaters, and does not rupture.

Riccia fluitans has a beautiful dichotomously-branched stem, and *R. natans* a broad lobed stem; they occur occasionally in water; *R. glauca* and other species occur on fields.

Order 2. ANTHOCEROTEÆ.

The thallus, which contains much chlorophyll and is irregularly branched, creeps on the ground. The archegonia are imbedded in the upper surface. The capsule is long and thin, like a pod; it splits open from above into two long valves; it contains a columella and elaters which have no spiral bands.

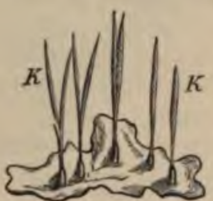


FIG. 107.—*Anthoceros lævis* (nat. size). *K* The capsules, some as yet unopened.

Anthoceros lævis (Fig. 107) and *punctatus* are found on loamy and sandy fields and woodland clearings; they are not common, but where they occur they grow in considerable quantity.

Order 3. MARCHANTIEÆ.

The archegonia and antheridia are usually collected respectively into groups on special upright, umbrella or hat-shaped branches, the *receptacles* (Fig. 108 *A hu*), of the thalloid stem: the stem bears on its upper surface numerous large stomata, and on its lower surface two rows of scaly inferior leaves and a number of root-hairs. The capsule contains elaters and opens irregularly, or by four valves, or by the removal of its upper part.

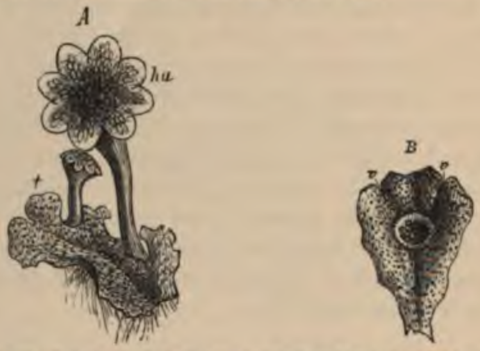


FIG. 108.—Portion of a stem of *Marchantia polymorpha* (*t*), with the upright male receptacle (bearing antheridia). *B* Portion of a stem with a receptacle containing gemmæ; *v v* apices of the two branches. (After Sachs.)

Marchantia polymorpha, which is very common on paths, on walls, and in peat-cuttings, has a thick, creeping, dichotomously-branched stem. The antheridia are borne on the upper side of umbrella-shaped branches (Fig. 108 *A hu*), and the archegonia on the under side of similar radiated receptacles. Besides these the stem produces from its upper surface cup-shaped vessels containing gemmæ (Fig. 108 *B*). *Fegatella conica* is similarly provided with a conical receptacle; in *Reboulia hemisphærica* it is semi-globular; these plants occur on rocks and damp walls, particularly in mountainous neighbourhoods.

Order 4. JUNGERMANNIEÆ.

The capsule splits into four valves from the apex downwards Elaters are present.

(*a*) *Anacrogynæ*. The archegonia are not borne at the apex of the thallus or stem, but on its upper surface; they are surrounded by an involucre formed by the stem or thallus: they are usually frondose.

Metzgeria furcata has a narrow dichotomously-branched thallus consisting of a single layer of cells, which is traversed by a midrib consisting of many layers; it grows very commonly on tree-trunks, but it rarely fructifies. *Pellia epiphylla* has a broad thallus, consisting of several layers of cells; it is not uncommon by springs, on damp rocks, etc. *Aneura pinguis* and other species occur in similar localities. *Blasia pusilla* has a thalloid stem; it grows on damp fields and by ditches.

(*b*) *Acrogynæ*. The archegonia are situated at the apex of the stem or of certain branches of it, and are surrounded by a perianth, that is, by leaves or part of leaves which form an investment. The stem does not usually bear inferior leaves, but always two rows of lateral leaves; these leaves are either bidentate at the apex, or bipartite, and sometimes (Frullania, Radula) are completely divided into two lobes. The insertion of the lateral leaves is at first transverse to the long axis of the stem, but it becomes modified by the unequal growth of the stem, so that the leaves come to be situated either on the lower (*folia succuba*) (Fig. 109), or on the upper (*folia incuba*) surface of the stem.

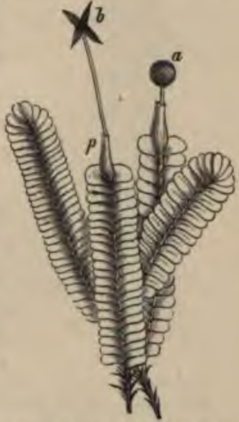


FIG. 109.—Stem of *Plagiochila asplenioides*. *a* A ripe capsule; *b* one that has opened; *p* Perianth.

Jungermannia bicuspidata and many other species are common on damp soil and on the trunks of trees. *Plagiochila asplenioides* (Fig. 109) is not uncommon in mountain woods. *Radula complanata* has a small stem, densely covered with leaves, which creeps over tree-trunks and boughs; it is very common. *Frullania dilatata* and *Tamarisci*, with small and elegantly-branched stems of a brownish or purple colour, also grow on trunks of trees, or on the earth, in damp, shady places.

CLASS IV.—MUSCI (TRUE MOSSES).

The capsule usually opens by the removal of a distinct operculum. Elaters are never present, the columella always. The calyptra is usually carried up by the capsule.

The Moss-plant always consists of a stem furnished with leaves, which are all of the same kind; its branches creep on the earth or else on trees, or they form dense plots. Bilateral structure does not very often occur.

The Class may be divided into four Orders:

Order 1. SPHAGNACEÆ (Bog-Mosses).

The spherical capsule contains a hemispherical columella, and opens by the removal of the upper portion of its wall; the calyptra remains attached to the base.

The only genus Sphagnum (Fig. 110) includes a number of species, which all live in damp woods, and more particularly on moors, forming extensive soft plots. The branches, which are densely covered with leaves, envelope the main stem: the leaves, as well as the cortex of the stem, contain large cells filled with water, the walls of which are perforated; by capillary attraction water is conveyed through these open cells to the topmost point of the plant. The lower portions of the quickly growing stems die off and form peat. The shortly-stalked capsule (Fig. 110 *K*) is raised by the elongation of the stem which bears the archegonium; this much resembles the stalk of the capsule (seta) in the true Mosses, but it is not of the same nature; it is called the *pseudopodium*.

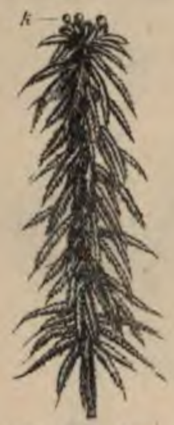


FIG. 110. — Stem of *Sphagnum acutifolium* (nat. size). *k* Capsules.

Order 2. ANDREÆACEÆ.

The columella is columnar in form, free at the top. The capsule splits into four valves, which remain connected at the base and apex. The calyptra is raised up as a cap upon the capsule.

The genus Andreæa (111 *b*) lives on rocks among the Alps and other high mountains. The elongated and branched stems are closely covered with leaves.

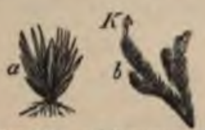


FIG. 111.—*a Ephemerum serratum* (× 3); *b* shoot of *Andreæa nivalis*, with (*K*) capsule (nat. size).

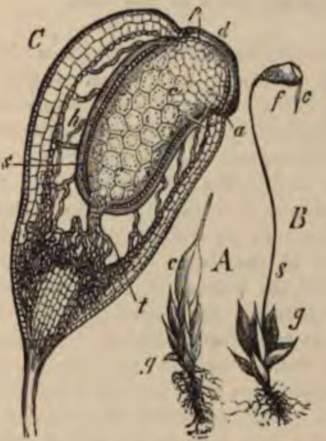
Order 3. PHASCACEÆ.

The capsule does not open at all; the columella, in this order and in the following, is connected with the wall of the capsule above and below. The spores in Archidium are formed from one of the cells of the columella: the calyptra remains at the base of the sporogonium.

Phascum cuspidatum, *Ephemerum serratum* (Fig. 111 *a*), and *Archidium phascoides* are minute Mosses a few millimetres in height, growing in fields and ripening their capsules in the spring.

Order 4. BRYINÆ.

The columella is connected with the capsule both at the top and at the bottom; it is immediately surrounded by the spore-forming tissue (Fig. 112 *s*); between this and the wall of the capsule there is a large cavity filled with air (Fig. 112 *h*) traversed by filaments of cells containing chlorophyll. The capsule opens by the throwing off of an operculum, which is from the first constructed differently to the rest of the capsule. Certain layers of cells of the internal tissue of this operculum remain in connection with the walls of the capsule and constitute the *peristome*, which has a characteristic form in each different genus. In Tetraphis it consists of four hard teeth, for which the whole of the internal tissue of the operculum is utilised; in most genera there are 8, 16, 32, or even 64 teeth, formed by the thickened cell-walls, which are frequently arranged in two rows, one within the other (Fig. 113), and which originate from two different layers of cells. In only a few genera, *e.g.*,



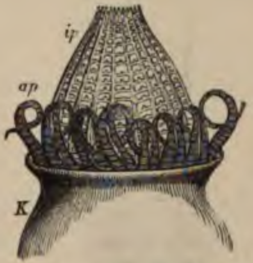


FIG. 113.—Mouth of the theca of *Fontinalis antipyretica*. *ap* Outer peristome; *ip* inner peristome (× 50).

FIG. 112.—*Funaria hygrometrica*. *A* A young leafy plant (*g*), with the calyptra (*c*). *B* A plant (*g*) with the nearly ripe sporogonium; *s* its seta; *f* the capsule; *c* the calyptra. *C* Longitudinal section of the capsule bisecting it symmetrically; *d* operculum; *a* annulus; *p* peristome; *c c'* columella; *h* air-cavity; *s* the primary mother-cells of the spores.

Gymnostomum, are they wholly wanting. The calyptra is elevated by the growth of the capsule and covers its apex like a cap; the capsule is generally elongated.

The leaves, which consist of a single layer of cells, are traversed by a many-layered midrib in many species.

Some of the genera bear the female flowers and, consequently, at a later stage the capsules also, on the apex of the main stems; others bear them on short lateral branches; although this difference of position cannot be regarded as an important systematic distinction, it may serve as an indication of allied forms. Thus the Bryinæ may be divided into:

(*a*) *Acrocarpi*, bearing the archegonia at the apex of the stem; the capsules, however, often appear as if they had been borne upon lateral shoots, for lateral shoots develope later and displace the main stem to one side.

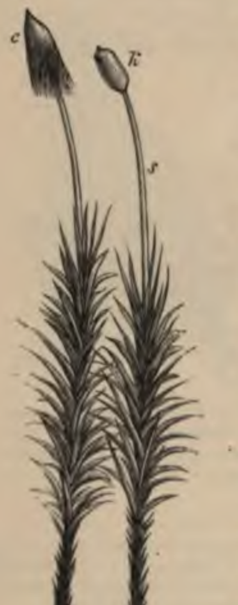


FIG. 114.—Two stems of *Polytrichum formosum* (nat. size). *k* the capsule; *s* the seta; *c* calyptra.

Dicranum scoparium, with sickle-shaped leaves, is common in woods. *Leucobryum glaucum* has leaves consisting of several layers of cells, which resemble those of Sphagnum in their structure; it occurs in Pine-woods and on moors. *Ceratodon purpureus*, with a red seta and a short stem, is very common in various localities. *Barbula muralis* grows in patches on walls and rocks; the midrib of the leaves is prolonged into a hair, so that the patches of Moss look greyish. *Tetraphis pellucida* has bright green leaves; it grows on decayed tree-trunks, and bears gemmæ of peculiar form. *Grimmia pulvinata* occurs in round greyish-green patches; the capsules have very short setæ. *Orthotrichum speciosum* and other species have also shortly-stalked capsules, and are common on trees. *Funaria hygrometrica* (Fig. 112) has an oblique, pear-shaped capsule; the long setæ have the peculiarity of contracting into a spiral on being wetted and dried; it is common on walls and paths. *Polytrichum formosum* (Fig. 114) and other species are the largest of our indigenous acrocarpous Mosses; they have large dark green leaves and long hairy calyptræ, and are common in woods and on heaths.

(*b*) *Pleurocarpi*. The archegonia, and subsequently the capsules, are borne on special lateral branches.

Fontinalis antipyretica floats in water. *Neckera crispa*, with flat outspreading leaves, grows on rocks. *Thuidium abietinum* and other species grow in woods; they have regular, pinnately branched stems, and very small, closely-set leaves. *Leucodon sciuroides* is very common on tree-trunks. *Brachythecium rutabulum* is common in woods. *Eurhynchium prælongum*, with long creeping stems, occurs in woods and damp gardens. *Hypnum cupressiforme* is very common on tree-trunks, and *H. cuspidatum* and *giganteum* in bogs and ditches. *Hylocomium triquetrum* is very commonly used for garlands; this and *H. splendens*, with remarkably regular ramification, are both common in woods.

GROUP III.

THE VASCULAR CRYPTOGAMS.

In this group also an alternation of a sexual with an asexual generation occurs; but the relations between the two are exactly the reverse of those existing among the Mosses. In this group the plant which springs from the spore and produces the sexual organs (the oophore) is small and short-lived, usually perishing after fertilisation has taken place; it is called the *prothallium*. The plant which grows from the fertilised oosphere (the sporophore) is furnished with a distinct stem and leaves, and it has closed fibro-vascular bundles and true roots; it commonly persists for several years and produces spores in regular succession, besides possessing various means of vegetative multiplication. These morphological

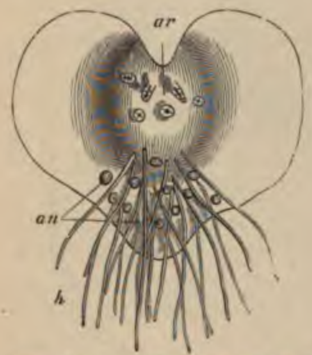


FIG. 115.—Prothallium of a Fern: under side (× 10). *ar* Archegonia; *an* Antheridia; *h* root-hairs.

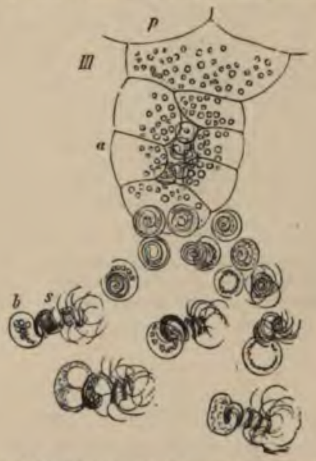


FIG. 116.—Antheridium of *Adiantum Capillus Veneris* (× 550). *p* Prothallium; *a* antheridium; *s* antherozoid; *b* the vesicle containing starch-grains.

and anatomical characteristics bring this group of plants into the province of the *Vascular Plants.* Some of the orders which occupy the highest place among the Cryptogams exhibit in certain features a resemblance to the Gymnosperms among the Phanerogams; there is thus a gradual transition from the Cryptogams to the Phanerogams.

The *Prothallium* (Fig. 115) is, in most of the orders, a thallus which grows from a spore which it greatly exceeds in size, producing, besides root-hairs, antheridia and archegonia on certain parts (Fig. 115 *an* and *ar*).

The *antheridia* (Fig. 116) either project from the surface as masses of tissue, which are hemispherical or somewhat cylindrical in form, or they are sunk in the tissue of the prothallium. They consist of a wall, composed of a single layer of cells, and of the mother-cells of the antherozoids: the antherozoid is a spirally wound filament bearing a number of cilia at its anterior end (Fig. 116 *s*).

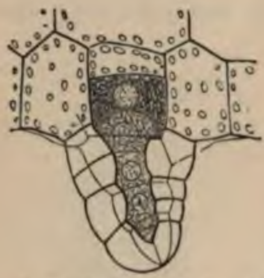


FIG. 117. — Archegonium of *Pteris serrulata*, much magnified, seen from outside. (After Sachs.)

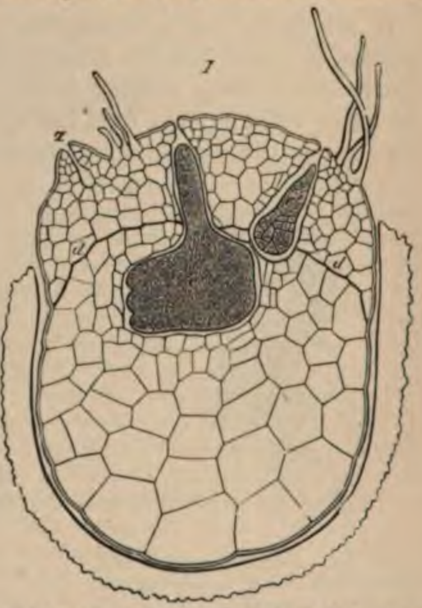


FIG. 118.—Germinating macrospore of *Selaginella Martensii*. The portion of the tissue which lies above the dark outline (*d*) is the prothallium; *a* is an unfertilised archegonium; *e e'* embryos in two that have been fertilised. The cavity of the spore is filled with endosperm. (After Sachs.)

The *archegonia* (Fig. 117) are in general constructed like those of the Mosses; that is to say, they consist of a ventral portion, which is imbedded in the surrounding tissue and is coherent with it, and of a short neck through which two canal-cells, which subsequently undergo disintegration, extend to the oosphere.

However, the prothallia of some orders, such as the Rhizocarpeæ, Selaginelleæ, and Isoëteæ, differ widely from this in their structure. These plants, namely, produce two kinds of spores, large spores called *macrospores*, and much smaller ones, *microspores*, and they are termed *heterosporous* on this account, in contrast to the *isosporous* orders in which the spores are all of one kind.

The *macrospore* produces a female prothallium (Fig. 118) which is developed in the spore itself, and only a small portion of it is exposed at the apex. On this exposed portion it bears one, or a small number of archegonia (Fig. 118 *a*).

The *microspore* produces a merely rudimentary male prothallium, for the antherozoids are developed from it directly, or at any rate after it has undergone only a few divisions.

The embryo developed from the fertilised oosphere grows directly into a plant which subsequently produces spores.

The spores are formed in not very large numbers in the *sporangia* by the division into four of the internal cells; and when two kinds of spores are present they are produced in distinct sporangia—*macro-* and *microsporangia*. The sporangia are small in proportion to the whole plant, and are developed either from single cells of the epidermis of the leaf, or from groups of cells, the external cells of each group forming the wall of the sporangium, the internal, the mother-cells of the spores. It is almost always evident that the sporangia are produced from the leaves; it is only in a few instances that they originate in the axils of the leaves and appear to be formed from the stem.

The group of Vascular Cryptogams is divided as follows:

Class V. *Filicinæ*. The leaves are well developed in proportion to the stem, and bear the sporangia (which usually originate from a single cell) almost always collected into *sori* on their margins or on their inferior surfaces; the fertile leaves are not confined to any particular region or branch of the stem.

(*a*) Isosporous.

Order 1. *Filices*.

(*b*) Heterosporous.

Order 2. *Rhizocarpeæ*.

Class VI. *Equisetinæ.* The leaves are small in proportion to the stem; they are arranged in whorls, and those of the barren whorls grow together into a sheath. The fertile leaves are arranged in numerous closely-set whorls forming a spike at the apex of the stem; they are peltate, and bear the sporangia on their under surfaces. The sporangia originate from groups of cells. They are isosporous.

Class VII. *Lycopodinæ.* The leaves are for the most part small and feebly developed; the fertile leaves are frequently collected on a distinct portion of the stem. The sporangia, which are developed from groups of cells, are almost always solitary in the axils of the leaves or close to the base of the leaves on its upper side.

(*a*) Isosporous.

Order 1. *Lycopodieæ.*

(*b*) Heterosporous.

Order 2. *Selaginelleæ.* The stem, which grows greatly in length, bears numerous small leaves; the sporangia are situated in the axils of the leaves, occasionally they are attached to some extent to the stem.

Order 3. *Isoëteæ.* The stem, which is short, bears long unbranched leaves; the sporangia are situated on the upper side of the leaf.

Class V.—FILICINÆ.

The sporangia are usually collected into sori on the edges or under surfaces of the leaves. The fertile leaves are not confined to a special region of the stem.

Order 1. Filices (Ferns).

The spores are all alike, and produce a large and independent prothallium.

The prothallium is almost always developed on the surface of the soil, and contains chlorophyll (Figs. 115 and 119). It takes origin from the spore in the form of a cellular filament which, at a later stage, generally becomes a broad surface divided anteriorly so as to be heart-shaped; it consists of a single layer of cells, excepting at that part which bears the archegonia. This region is situated at the fore part of the heart-shaped prothallium, behind the indentation (Fig. 115 *ar*). The antheridia are produced partly at the edge, and partly posteriorly among the root-hairs (Fig. 115 *an*), and project as hemispherical masses of tissue.

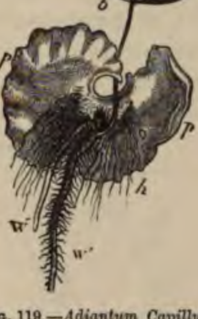


FIG. 119.—*Adiantum Capillus-Veneris.* The prothallium (*p p*) seen from below with young Fern attached to it; *b* its first leaf; *w' w''* its first and second roots; *h* root-hairs of the prothallium (about × 3). (After Sachs.)

The stem is for the most part a strong underground horizontal or oblique rhizome; tree-ferns with tall upright trunks occur only in the tropics. The internodes are sometimes elongated, so that the surface of the stem is visible between the leaves which are some distance apart, *e.g.*, *Pteris aquilina* (the common Bracken) and *Phegopteris calcarea;* but they may be also very short, so that the leaves form a close crown at the apex of the stem, while the older portion is closely crowded with the remains of the leaves that have died off. The stems of the first kind usually branch very freely, the branches arising in the axils of the leaves, as in *Phegopteris calcarea*, or dorsally to them, as in *Pteris aquilina:* the more leafy stems, on the contrary, branch less. The leaves are sometimes arranged in two rows, particularly when the stem is elongated (*e.g.*, *Pteris aquilina*); and this peculiarity is not unfrequently exhibited, that the two series of leaves approach each other on the dorsal surface of the stem, *e.g.*, *Polypodium vulgare;* but they are sometimes arranged in a spiral, with a considerable angle of divergence. The blade of the leaf is usually much branched, and in its early growth it is curled spirally forward on itself into the shape of a crozier (circinate vernation). The hairs are often conspicuous by their size and breadth, and frequently completely envelope the young leaves and the growing part of the stem; they are called *paleæ* or *ramenta*. The roots spring usually from the leaf-stalks of those species the stem of which is very densely covered with leaves, *e.g.*, *Nephrodium Filix-mas;* they form a thick felt-like covering on the trunks of tree-ferns, which sometimes exceeds the diameter of the stem itself in thickness.

The production of spores is exclusively confined to the leaves, and it takes place without their undergoing any important metamorphosis. In many cases the fertile leaves are hardly to be distinguished from the barren ones, and where a difference is perceptible, it consists almost only in this: that the fertile leaf—or portion of the leaf—developes little or no mesophyll. The fertile leaves are never confined to a particular region of the stem, still less to any particular branch; but the stem bears at first only barren leaves, and, as it grows older, produces fertile leaves periodically, as well as sterile ones.

The *Sori* consist of groups of sporangia which are arranged in a certain relation to the venation of the leaves, and their form and distribution is characteristic of genera and even of still larger divisions. In many genera, *e.g.*, all the Hymenophyllaceæ (Fig. 120 *A*), Dicksonia and Davallia, the sorus is situated at the margin of the leaf at the extremity of a vein, and consists of two parts, a central

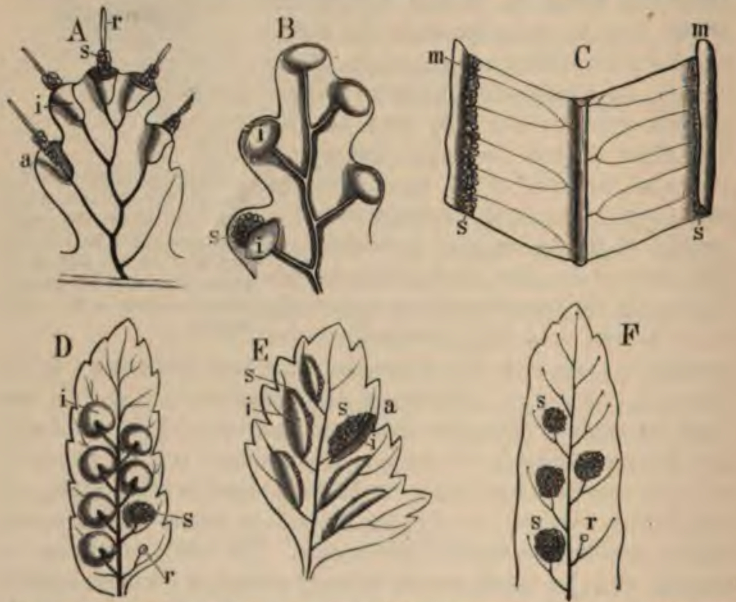


Fig. 120.—Sori of the most important groups of Ferns, all seen from below. *A* Pinna of *Ptilophyllum sinuosum*, one of the Hymenophyllaceæ; *r* receptacle; *s* sporangia; *i* indusium; at *a* half of the indusium is removed. *B* Pinna of Davallia—at *s* the underside of the indusium (*i*) is turned back, the upper half is become part of the leaf margin. *C* Part of a leaf of *Pteris serrulata*: *s* the sporangia; *m* the inverted margin. *D* Lacinia of Nephrodium—at *s* the indusium is removed, and at *r* the sporangia also. *E* Lacinia of an Asplenium—at *a* the indusium is turned back. *F* Pinna of *Polypodium vulgare*—at *r* the sporangia are removed (all are × 3 to 6).

part which bears the sporangia, known as the *receptacle* (Fig. 120 *A r*), which is an elongated, filiform, or short cushion-like structure, and a cup-shaped, sometimes deeply two-lobed integument, the *indusium* (Fig. 120 *A i*). In most Ferns the sorus is at some distance from the margin of the leaf, on the under surface; the indusium then appears as covering the receptacle on one side only (Fig. 120 *B D E*), and its form varies in the different genera. The half of the primitively cup-shaped indusium, corresponding to the upper surface of the leaf, has disappeared (Fig. 120 *B*). In many genera the indusium has disappeared altogether; the sorus is then said to be naked (Fig. 120 *F*). Many Ferns bear the sporangia in a marginal row which may be supposed to have originated by the coalescence of contiguous sori. The inferior indusium, in such cases, is usually not present: the margin of the leaf covers the sporangia as a so-called spurious indusium (Fig. 120 *C*). Finally, in some Ferns, the sporangia do not form sori, but are scattered over the whole of the under surface of the leaf, on the mesophyll as well as on the veins. The hair-like structures which the receptacle sometimes bears interspersed among the sporangia are known as *paraphyses.*

The *Sporangium* (Fig. 121) is a capsule with a wall of a single layer of cells, and having a short stalk; it is rarely sessile. The spores commonly originate from the repeated division of a single cell which occupies the centre of the young sporangium; in only a few families the sporangium is developed from a group of cells, of which the inner cells constitute the mother-cells of the spores. In direct relation to the mode of rupture of the sporangium are certain cells, which have a peculiar structure, and which are much thickened; they form a *ring* or *annulus*, which, in some families, is completely closed, and in others not so (Fig. 121 *r*), or they may be connected in some other form, but in any case the aggregate of these cells is spoken of as the annulus (Fig. 122 *r*). The structure of this annulus is an important characteristic of the various families.

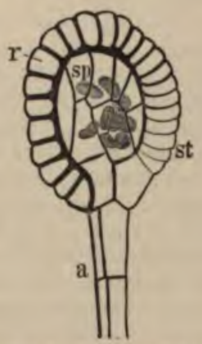


FIG. 121.—Sporangium of one of the Polypodiaceæ (× 300): *a* stalk; *r* the ring which extends to the stomium *st*, at this spot the wall of the sporangium ruptures. Only a few of the spores (*sp*) are indicated, for the sake of distinctness.

The group of the Ferns includes the following eight families, of which some are exclusively tropical, and the others, though they have representatives in temperate climates, attain their most perfect development in the tropics.

Family 1. *Hymenophyllaceæ;* this contains the simplest forms. The mesophyll almost always consists of a single layer of cells; the sorus is always marginal (Fig. 120 *A*), the sporangium sessile or shortly-stalked, and the annulus entire. The prothallium resembles in structure the protonema of Mosses.

Almost all the species are tropical. *Trichomanes radicans* and *Hymenophyllum Tunbridgense* and *unilaterale* (or *Wilsoni*) alone occur in England. Some species of Trichomanes have no true roots.

Fam. 2. *Polypodiaceæ.* The annulus of the stalked sporangium is incomplete (Fig. 121 *r*), that is to say, it is not continuous at the base: each sporangium is developed from a single epidermal cell. Almost all our native Ferns belong to this family, which is exceptionally rich in species.

The following sub-families may be distinguished, characterized by the position of the sorus.

(*a*) *Davalliaceæ.* Sorus marginal, or nearly so; indusium cup-shaped (Fig. 120 *B*).

(*b*) *Pterideæ.* Sori coalescent along the margin of the leaf (Fig. 120 *C*); indusium spurious. *Pteris aquilina*, the Bracken, has a stem which grows at some depth below the surface of the soil and throws up every year a single large much-segmented leaf (frond). Adiantum, the Maiden-Hair, and Blechnum (Lomaria), the Hard-Fern, belong to this group.

(*c*) *Aspidieæ.* Sorus on the lower surface of the leaf, orbicular in form and covered by a peltate or reniform indusium (Fig. 120 *D*). *Nephrodium Filix mas*, the male Fern, and other species resembling it, with a thick tufted crown of leaves, are not rare in woods. Aspidium is the Shield-Fern. Woodsia and Cystopteris also belong to this group.

(*d*) *Asplenieæ.* The sorus, which is situated on the under surface of the leaf, is elongated or linear, and the indusium springs from the vein to which it is attached (Fig. 120 *E*). *Asplenium Ruta muraria* is not uncommon on walls and rocks; *A. Trichomanes* is also abundant, with simple pinnate leaves and a shining black rachis. *A. Filix fœmina* is common in damp woods. *Scolopendrium vulgare*, the Hart's tongue, with entire leaves, is common in damp hedgerows and woods.

(*e*) *Polypodieæ.* The sorus, which is on the under surface of the leaf, is naked (Fig. 120 F). In the section Polypodium the leaves are articulated to the stem, so that when they die and fall off they leave a roundish scar: the leaves are usually borne in two rows on the dorsal surface of the rhizome. *Polypodium vulgare*, with simple pinnate leaves, is common on tree-trunks, rocks, etc. In the section Phegopteris the leaves are not articulated to the stem, so that when they die fragments of the leaf-stalks remain attached to it.

(*f*) *Acrosticheæ.* The whole underside of the leaf is covered with sporangia.

Fam. 3. *Cyatheaceæ*. Distinguished from the Polypodiaceæ only by the presence of a complete annulus.

The tree-ferns belong to this family. Cibotium and Dicksonia have marginal sori with cup-shaped indusia: Cyathea and Alsophila have their sori on the under surface of the leaf.

Fam. 4. *Gleicheniaceæ* and

Fam. 5. *Schizæaceæ* occur only in the tropics.

Lygodium is the most remarkable genus, its pinnate leaves grow to a great length and twine round supports by means of their midribs.

Fam. 6. *Osmundaceæ*. The shortly-stalked sporangia (Fig. 122 *B*), instead of a ring, have a peculiar group of cells (Fig. 122 *B r*) just below the apex; they burst open by a longitudinal slit on the side opposite to this (Fig. 122 *d*).

Osmunda regalis, the Fern-Royal, is a not very common but well-known Fern. Only the upper pinnæ of the leaves are fertile and develope little or no mesophyll; the sori are marginal and consist of a great number of sporangia: they have no indusium, Fig. 122 (*A s*).

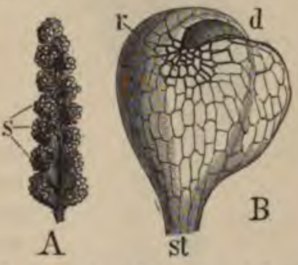


FIG. 122.—*Osmunda regalis*. *A* Fertile pinna with naked marginal sori (*s*). Some mesophyll is, however, developed at the base (nat. size). *B* A solitary sporangium (×200); *st* the short stalk; *r* the annulus; *d* the longitudinal slit.

Fam. 7. *Marattiaceæ*. The sporangia of each sorus are coherent, and appear as the loculi of a multilocular sporangium or *synangium*: they are not developed each from a single cell, but from a group of cells. The leaves, which are usually of enormous dimensions, have large stipules at their base.

Marattia, Kaulfussia, Angiopteris, and Danæa are tropical genera.

Fam. 8. *Ophioglosseæ*. This is the most aberrant of the families of Ferns; nevertheless it is allied to the above-mentioned families by many features. The prothallium is not a flat layer of cells containing chlorophyll, but a subterranean mass of tissue, containing no chlorophyll. The stem of the spore-bearing plant is always short, and in the indigenous species it is subterranean; it throws up a single aërial leaf, or two or three simultaneously. The leaves to be developed in the following year are already formed at the end of the stem and are enclosed in a sheath formed by the base of the mature leaf and its stipules. The fertile leaves are distinguished from the barren ones by the production, from the upper side of the petiole, of a branch which bears the fructification. The sporangia are large and marginal, and are borne either directly by this branch, as in Ophioglossum, or by its lateral branches, as in Botrychium (Fig. 123 *f*). The sporangia are developed from groups of cells and have no annulus. In Ophioglossum they are sunk in the tissue.

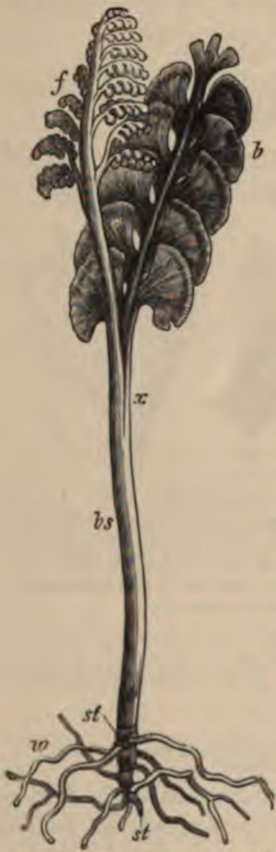


FIG. 123.—*Botrychium Lunaria* (nat. size): *w* roots; *st* stem; *bs* leaf-sheath; *x* point where the leaf branches; the sterile lamina (*b*) separating from the fertile branch (*f*).

Ophioglossum vulgatum is rather rare: it has an entire tongue-shaped lamina and a linear unbranched fructification. *Botrychium Lunaria* is tolerably common in mountainous districts; its lamina is pinnate and the fructification is paniculate.

Order 2. RHIZOCARPEÆ (PEPPERWORTS).

The spores are of two kinds; the macrosporangia each contain a single macrospore; the microsporangia contain numerous microspores; the prothallia are small and project but little from the spores.

Fam. 1. *Salviniaceæ.* Salvinia is the only genus. The male prothallium is a filament which is developed from the microspore. The antherozoids are formed in two cells at the free end of this filament, which represent a rudimentary antheridium.

The female prothallium projects but little from the spore.

The stem of the spore-bearing plant floats on the surface of the water and bears on its upper surface four rows of flat, green, aërial leaves (Fig. 124 *l*) and on its under surface two rows of dissected aquatic leaves (Fig. 124 *w*). Roots are wholly absent. The sori are situated on the aquatic leaves (Fig. 124 *s*); each separate sorus is completely enclosed in a thick indusium, and has a diameter of about 5 millimetres. Within this fructification the sporangia are borne on a columnar receptacle; in some sori there

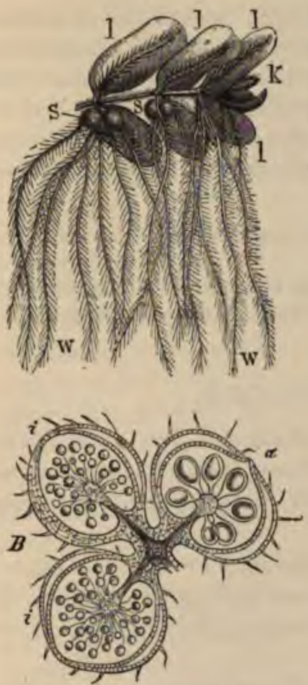


Fig. 124.—Apical portion of the stem of *Salvinia natans*, seen obliquely from below (nat. size): *l l* aërial leaves; *w w* aquatic leaves, with a sori, *s s*; *k* terminal bud of the stem. *B* Longitudinal section through three fertile teeth of an aquatic leaf (× 10); *i i* two sori with microsporangia; *a* one with macrosporangia. (After Sachs.)

are numerous microsporangia with long stalks (Fig. 124 *B i i*), in others a smaller number of shortly-stalked macrosporangia (Fig. 124 *B a*).

Salvinia natans occurs in the warmer parts of Europe and in the Tropics.

Fam. 2. *Marsiliaceæ.* This family includes two genera, Marsilia and Pilularia. The formation of a male prothallium does not take place; the whole contents of the microspore undergo division and give rise directly to a number of small cells, in each of which an antherozoid is formed.

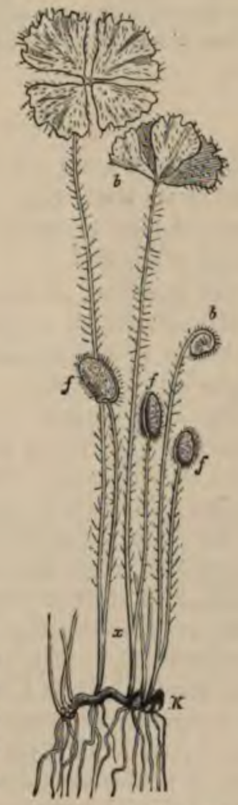


Fig. 125.—Stem of *Marsilia salvatrix* with leaves (reduced one-half). *K* Terminal bud; *b b* leaves; *f f* fructifications springing from the petioles.

The stem of Marsilia creeps along the bottom beneath the water (Fig. 125) and bears on its upper surface two rows of leaves with long petioles and quadrifoliate laminæ. The under surface of the stem bears only roots. The fertile leaves branch above their insertion; the one branch is quite similar to a sterile leaf, the other bears a leguminoid fructification (Fig. 125 *f*), which contains several sori enclosed by indusia. This fructification, like those of the Phanerogams, consists of an infolded leaf. The sporangia are developed each from a single cell on the inner surface of the wall of the fructification. Each sorus contains both macro- and micro-sporangia.

Marsilia quadrifolia occurs in temperate countries, and many other very similar forms abound in warmer climates.

Pilularia globulifera has narrow bladeless leaves, and the fructification is globose, but otherwise it greatly resembles Marsilia. It occurs in England.

CLASS VI.—EQUISETINÆ.

The fertile leaves are arranged in whorls and form a spike at the apex of the stem; they are peltate and bear the sporangia, which are developed from groups of cells, on their inner surfaces. The spores are all of one kind.

This class contains but one genus, Equisetum (the Horsetail).

The prothallium is much branched and corrugated: it bears the antheridia at the extremities of the lobes, and the archegonia in the angles between them.

The spore-bearing plant consists of a subterranean colourless stem which every year throws up green branches which usually die down in the autumn. The leaves are represented by an annular dentate leaf-sheath at each node (Fig. 126 *A v*). The outer surface of the aërial internodes is usually not smooth, but striated with longitudinal ridges and furrows (Fig. 126 *B*): each ridge corresponds to a tooth of the leaf-sheath. This external configuration of the stem is intimately connected with its internal structure. The fibro-vascular bundles are arranged in a circle (Fig. 126 *B s*), in each bundle there is a cavity, the lacuna (*k*), which is formed by the separation of the annular vessels; the fibro-vascular bundles lie on the same radii as the ridges on the stem. There are also large cavities in the cortical tissue which lie internally to the grooves (Fig. 126 *B f*). The pith too is replaced by a large air-space, the central cavity (Fig. 126 *B c*). The branches spring from the base of the sheath between the teeth; they are similar in structure to the main stem.

The fertile branches terminate in a spike (Fig. 126 *A a*), formed of the leaves, which are transformed into peltate scales bearing sporangia. The last leaf-sheath below the spike is rudimentary, and is called the *ring* or *annulus* (Fig. 126 *A w*). The scales stand in numerous whorls; they have stalks and bear the sporangia on their internal surface. The sporangia are sac-like and open inwards by a fissure (Fig. 126 *C sp*). The spores are enclosed by two coats, the two being connected at one point only. The outer membrane splits along a spiral line into two spiral bands (*elaters*) which, when they are dry, are extended cross-wise, but roll up under the influence of moisture.

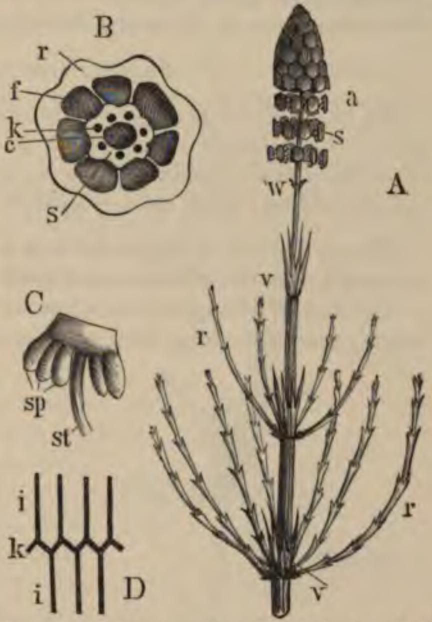


FIG. 126.—*A* Upper portion of a fertile branch of *Equisetum palustre*. *v* Leaf-sheaths, below which the branches (*r*) spring; *w* the uppermost sterile sheath; *a* the spike; *s* the peltate fertile leaves. *B* Transverse section of the stem (× 6): *c* central cavity; *s* the fibro-vascular bundles arranged in a circle, each having a cavity, *k*; *f* the cavities below the groves; *r* the ridges. *C* Peltate leaf with sporangia (× 10): *st* the stalk; *sp* the sporangia. *D* Diagram of the course taken by the fibro-vascular bundles where two internodes meet; *i i* the internodes; *k* the node.

The different species of Equisetum all inhabit damp places, bogs, wet fields, and woods. While some of the tropical forms attain an immense height and thickness, and the fossil forms were of gigantic proportions, our indigenous species reach at the utmost the height of a few feet, and a thickness of perhaps half an inch. In *E. arvense* and *E. Telmateia* the fertile shoots appear in the spring before the barren ones, and are devoid of chlorophyll, while the barren ones are green. *E. palustre* (Fig. 126), *limosum*, *hyemale*, etc., bear their spikes at the extremity of ordinary green branched or unbranched shoots. *E. sylvaticum* produces fertile shoots which, till the spores are ripe, perfectly resemble those of *E. arvense*, which are devoid of chlorophyll, but afterwards they bear green lateral shoots, in consequence of which they come to be very similar to the sterile stems.

CLASS VII.—LYCOPODINÆ.

The leaves are for the most part small, the fertile leaves often confined to a particular region of the stem. The sporangia, which are developed from groups of cells, are almost always borne in the axils of the leaves or close to the bases of the leaves on their upper sides.

Order 1. LYCOPODIEÆ.

The spores are all of one kind, the prothallium large and independent. The sporangia are outgrowths from the bases of the leaves, and are situated in their axils. The stem grows greatly in length and bears numerous leaves; which are very small in proportion.

The prothallium of Lycopodium is a subterranean mass of tissue of considerable size which bears archegonia and antheridia.

The stem of the spore-bearing plant grows greatly in length: it usually creeps on the ground and branches in various planes in an apparently dichotomous manner. The internodes are short, the leaves are closely placed in a scattered spiral, or they are decussate. The roots branch dichotomously. The sporangia originate from the tissue of the upper surface of the fertile leaves and project outwards. The fertile leaves, in some species, *e.g.*, *Lycopodium Selago*, exactly resemble the sterile ones; in others they differ from them and are not green: in this case they form a sort of spike which in *L. clavatum* grows on a stalk bearing small leaves (Fig. 127 *s*).

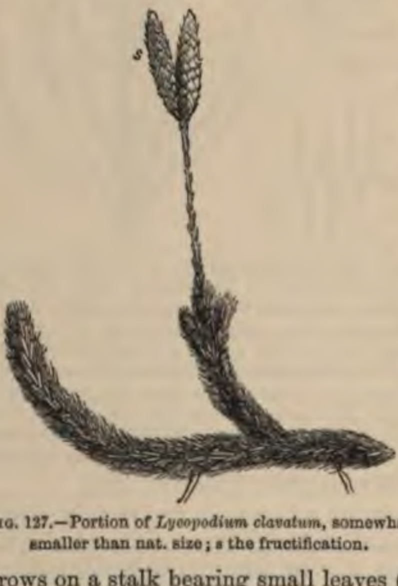


FIG. 127.—Portion of *Lycopodium clavatum*, somewhat smaller than nat. size; *s* the fructification.

L. clavatum and *annotinum* (Club-Mosses), are the commonest species which occur in our woods. The exotic genera Tmesipteris, Phylloglossum, and Psilotum (which has no true roots) differ considerably from Lycopodium in their habit, but are as yet imperfectly known.

Order 2. Selaginelleæ.

The spores are of two kinds; the macrosporangia each contain four macrospores, the microsporangia, a great number of microspores; both forms of sporangia are situated in the axils of the leaves. The prothallia are small and project but little from the spores. The stem grows considerably in length and bears numerous short leaves.

The genus Selaginella has some external resemblance to Lycopodium; the stem branches dichotomously, but always in the same plane, and often forms a highly complicated branch-system. In some species the stem creeps on the ground, in others it is upright and even shrubby. The internodes are short, and bear short somewhat rounded leaves, which are usually inserted in four rows and have different forms on the two sides of the stem, so that each pair of decussate leaves consists of a large inferior leaf and a small superior leaf (Fig. 128 *u* and *o*). At the base of each leaf there is a small membranous *ligule*. The roots branch dichotomously in alternate planes at right angles to each other. The sporangia are situated in the axils of the fertile leaves, which sometimes differ somewhat in form from the sterile ones. The microsporangia are usually higher up on the shoot than the macrosporangia. Each of the latter contains four macrospores, for only one of the numerous mother-cells divides into four daughter-cells, which are developed into macrospores.

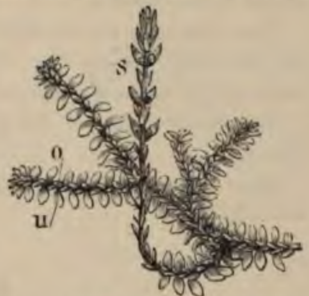


FIG. 128.—*Selaginella helvetica* (nat. size): *s* the upright fertile shoot, with sporangia in the axils of the leaves. On the procumbent sterile shoots, the leaves on the under side (*u*) are larger than those on the upper side (*o*).

The prothallium is formed in the macrospore, just beneath the apex, whilst it is ripening: subsequently, when the spore germinates, the prothallium protrudes from the apex of the spore, the wall having ruptured along its three angles, and it there bears one or more archegonia. The rest of the cavity of the spore is then filled with a parenchymatous tissue, which may be termed the *endosperm* (Fig. 118).

In the microspore the prothallium is only rudimentary; it is represented by one cell, which undergoes no further changes, whilst from the others the mother-cells of the antherozoids are formed by repeated division.

S. selaginoides **is the only indigenous species; it grows in bogs and marshes. Several species, such as *S. Kraussiana, inæqualifolia*, etc., are cultivated.**

Order 3. ISOËTEÆ.

The spores are of two kinds; the macrospores are numerous in the macrosporangia. Both kinds of sporangia are situated at the bases of the leaves on their upper surface. The prothallium is small and projects but little from the spore. The stem remains short and bears numerous long leaves.

The genus Isoëtes includes aquatic plants which live at the bottom of lakes, etc. The stem is short; along two or three longitudinal lines on the stem a considerable growth of the cortical tissue forms projecting wings, between which the roots are produced. The leaves, which are numerous, have a well-developed sheath separated from the long and narrow lamina by a pit, the *fovea*, which bears a ligule on its upper margin.

The sporangia are situated in this pit; the macrosporangia occur on the outer leaves, the microsporangia on the inner ones. Both sorts of sporangia contain cellular filaments among the spores.

The development of the prothallium is similar to that of Selaginella.

Isoëtes lacustris **and other species occur in lakes where the water does not contain much lime.**

GROUP IV.

PHANEROGAMS.

The most conspicuous character of this group is the formation of *seeds*, which are produced, in consequence of fertilisation, upon the plant itself, and are detached from it only at maturity. The seed contains enclosed in its coat, or *testa*, an *embryo*,—that is to say, a young plant. This is usually already so far developed that stem, leaves, and root are formed to a certain extent, so that after a period of rest it at once developes, at the time of germination, into an individual resembling its parent. Besides the embryo, the seed usually includes a tissue, called the *endosperm*, which in many orders is absorbed by the embryo at an early stage before the seed is ripe, and in a few others is never developed at all.

In the Vascular Cryptogams, the structures which are thrown off for the purpose of reproducing the plant are unicellular spores, which more or less directly give rise to the sexual organs; but in the

Phanerogams, fertilisation takes place upon the plant (sporophore) itself, and the structure which is thrown off for the purpose of reproduction is an embryo invested by parts of the parent plant.

As in many of the Vascular Cryptogams (Equisetum, many Selaginelleæ and Lycopodieæ), the spore-bearing leaves differ in form from the foliage-leaves, and are collected together on certain regions of particular short axes, so in the Phanerogams the reproductive organs are modified leaves which are collected together at the apex of a short axis. This shoot, the leaves of which are thus modified to subserve reproduction, is called the *Flower*.

The most important organs of the flower are the *stamens*, bearing the *pollen-sacs* in which the male reproductive bodies, the *pollen-grains*, are contained (Fig. 129 p), and the *carpels*, which usually bear the *ovules;* within the ovule the *oosphere* is situated (Fig. 129 E).

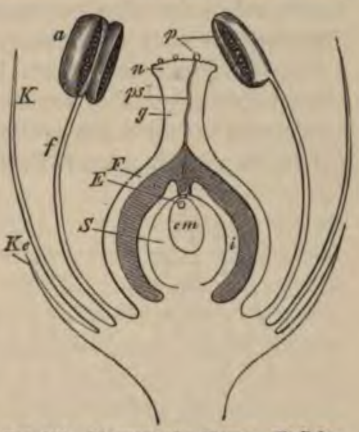


FIG. 129.—Diagram of a Flower. *Ke* Calyx. *K* Corolla; *f* filament; *a* anther with two pollen-sacs in each half, which are opened, showing the pollen-grains (*p*). These fall on the stigma, and the pollen-tube (*ps*) penetrates the style (*g*) as far as the cavity of the ovary (*F*), reaching the ovule (*S*); *i* the integument of the ovule; *em* the embryo-sac. *E* The oosphere.

The stamens, regarded collectively, form the *andrœcium* of the flower, and the carpels the *gynœcium*. In addition to these, the flower includes other foliar organs which, however, are not directly concerned with reproduction: these form the *perianth* (Fig. 129 *Ke K*). When these three sets of organs are all present in a flower, the perianth is always situated most externally, that is, at the lowest level upon the floral axis; then comes the andrœcium, and finally, nearest to the apex of the axis, the gynœcium.

The pollen-grains are formed in the pollen-sacs by the division of the mother-cells into four. The wall of the pollen-grain consists of two layers, an external, the *extine*, which is firm and often covered with asperities; an internal, the *intine*, which is very thin: the cell-contents consist of granular protoplasm, which has been termed *fovilla*. In the Angiosperms two or more nuclei are present in the pollen-grain, and the protoplasm is aggregated round them so as to form masses of various sizes; although these masses are not covered with cell-walls, they must be regarded as being cells. In the Gymnosperms, however, each of these cells has a cell-wall, and the pollen-grain is therefore obviously multicellular. The *pollen-tube*, by means of which fertilisation is effected, consists of the intine and the contents of the grain; it grows out, through the ruptured extine, from the largest of the cells contained in the pollen-grain.

The pollen-grains correspond to the microspores of the higher Vascular Cryptogams. The fact that they are multicellular recalls the rudimentary prothallium formed in the microspores of Selaginella, but no formation of antherozoids takes place. The pollen-sacs correspond to the microsporangia, and the whole stamen to a leaf of Selaginella bearing a microsporangium.

The carpels are either open, bearing the ovules on their surfaces (Gymnosperms), or they form, or contribute to form with the axis, a structure in which the ovules are contained, the *ovary* (Fig. 129 *F*), which, when mature, is the *fruit* (Angiosperms).

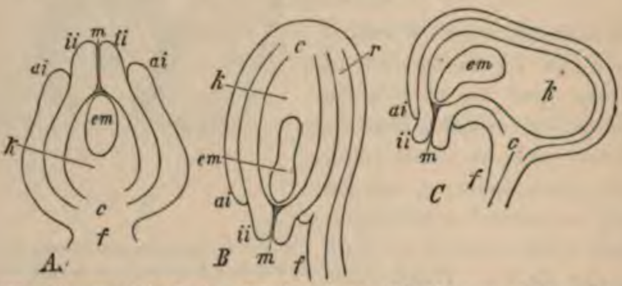


FIG. 130.—Diagram of the Ovule. *A* Orthotropous. *B* Anatropous. *C* Campylotropous; *f* funicle; *ai* the outer integument; *ii* the inner integument; *m* micropyle; *k* nucellus; *em* embryo-sac; *r* the raphe; *c* chalaza.

The Ovule consists of three parts:

1. A stalk, called the *funicle*, by which it is attached to the parent plant (Fig. 130 *f*): the point of junction of the funicle with the ovule is termed the *hilum*.

2. One or two coats, the *integuments* (Fig. 130 *ai ii*), which do not completely close at the anterior end, but leave a short canal known as the *micropyle* (Fig. 130 *m*): the point of junction of the nucellus with the integuments is termed the *chalaza* (Fig. 130 *c*): in some cases (Fig. 130 *A*, *C*) the chalaza and hilum coincide, in other cases they may be more or less widely separated, as in Fig. 130 *B*, where they are separated by the whole length of the ovule.

3. A central cellular mass, the *nucellus* (Fig. 130 *k*).

According to the relative position of these three parts, the following forms of ovules are distinguished:

a. Atropous or *orthotropous*, when the nucellus lies in one and the same straight line with the funicle which is usually short (Fig. 130 *A*).

b. Anatropous (Fig. 130 *B*), when there is a curvature at the point of attachment of the nucellus with its integuments (hilum) to the elongated funicle (*raphe*), the integuments coalescing with the raphe.

c. Campylotropous (Fig. 130 *C*), when the nucellus with its integument is curved on itself.

One cell of the nucellus increases greatly in size and constitutes the *embryo-sac*, within which, at the anterior end of the ovule (that is to say, the end at which the micropyle is situated), is the oosphere: in Angiosperms this cell is developed directly by free cell-formation (see p. 205), but in Gymnosperms it is formed indirectly in a special organ, the *corpusculum* (see p. 177).

Fertilisation is effected as follows: a pollen-grain falls either directly upon the micropyle, as in the Gymnosperms, or on to the apex of the ovary, which is specially adapted to receive it, as in the Angiosperms, and it then throws out a long tube, known as the pollen-tube (Fig. 129 *ps*). This extends to the oosphere (Fig. 129 *E*) through the micropyle, and the oosphere is fertilised in consequence of the contact. The result of the fertilisation is that this cell becomes surrounded by a membrane and begins to grow towards the interior of the embryo-sac, forming a row of cells, the *suspensor*, of which the inferior terminal cell forms the embryo by cell-division.

A parenchymatous tissue is developed within the embryo-sac, the *endosperm*, in the Gymnosperms before fertilisation, in the Angiosperms not until after it. It usually originates by free cell-formation, isolated cells being formed in considerable numbers which, as they grow, come into contact and then multiply still further by division. In rare cases (*e.g.*, Alismaceæ) the formation of endosperm does not take place. In many plants the endosperm is displaced and consumed by the developing embryo, so that it has disappeared by the time that the seed is ripe.

In contradistinction to the endosperm, the term *perisperm* is applied to the cellular tissue which is contained within the ovule, but which lies externally to the embryo-sac: it is in fact a permanent portion of the nucellus, and it is found in relatively few families of plants (Fig. 157).

The comparison of the female sexual organs and of the modes of fertilisation of Phanerogams with those of the Vascular Cryptogams is somewhat difficult, and will be entered upon when the Gymnosperms are being considered.

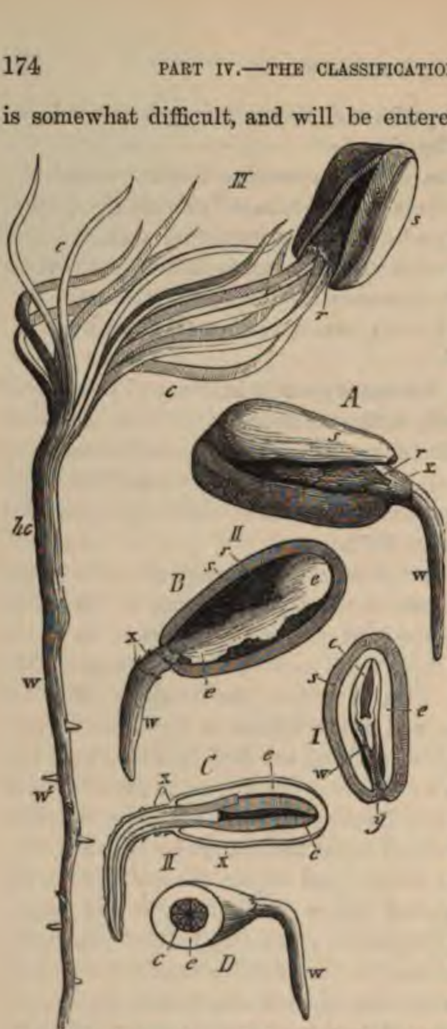


FIG. 131.—*Pinus pinea.* *I* Longitudinal section through the middle of the seed; *y* the micropylar end. *II* Commencement of germination, emergence of the root. *III* Completion of germination, after the endosperm has been absorbed (the seed lay too near the surface, and was therefore raised up by the cotyledons when the stem began to grow). *A* Shows the ruptured testa (*s*). *B* The endosperm (*e*), one-half of the testa having been removed. *C* Longitudinal section of the endosperm and embryo. *D* Transverse section at the commencement of germination; *c* the cotyledons; *w* the primary root; *x* the embryo-sac pushed out by it (ruptured in *B*); *hc* hypocotyledonary portion of the axis; *w'* secondary root; *r* red membrane within the hard testa.

The embryo, as it is contained in the ripe seed, usually exhibits distinct differentiation into *stem*, *leaf*, and *root*. This first root (Fig. 131 *w*)—the *primary root*—lies in the same straight line as the stem which is very short. At the opposite end the stem bears the first leaves (Fig. 131*c*) which are usually strikingly unlike the leaves of later growth, and are known as *cotyledons* or seed-leaves. Sometimes the next leaves are distinctly visible, forming a terminal bud, and these constitute the *plumule*. The portion of the stem which lies below the cotyledons is the *hypocotyledonary* portion (Fig. 131 *III h c*); it merges gradually into the root, and the two together are designated as the *radicle*. The internode next above the cotyledons is the *epicotyledonary* portion. The embryo always lies so in the ovule that the apex of the primary root is directed towards the micropyle; on germination the root grows out through it. The integuments of the ovule constitute the *testa* of the ripe seed, and occasionally during the ripening process another outer integument is formed, known as the *arillus*, as in the Yew and the Spindle-tree.

All flowers do not consist of the three parts above-mentioned, the perianth, the andrœcium, and the gynœcium; the perianth, for instance, is absent in many flowers. Those flowers which include both male and female organs are called *hermaphrodite*, commonly indicated by the sign ☿; but there are many plants in which some of the flowers (irrespectively of the perianth, which may be present or absent) possess male organs only, and others female organs only. Such flowers are called *diclinous* or *unisexual*, the former being male (♂) and the latter female (♀). When the flowers of both sexes are borne by one individual plant, they are said to be *monœcious;* but when they occur on distinct plants, they are said to be *diœcious:* it is permissible in that case to speak of male and female plants. When the same plant produces both hermaphrodite and unisexual flowers, it is said to be *polygamous*.

Plants of which the individual perishes after once producing flowers and seeds are termed *monocarpous;* in rare cases several or even many years elapse before the blossoming occurs, *e.g.*, *Agave americana*. More common are *annuals* (indicated by the sign ⊙), *i.e.*, plants which complete the whole course of their development in the course of a single year, as the Wheat; or *biennials* (⚇), plants which do not blossom till the second year of their growth, and then perish, as the Turnip. By *polycarpous* plants are meant those of which each individual produces flowers and fruit repeatedly, year after year; trees and shrubs are thus perennial, and have sub-aërial woody stems or trunks, and there are perennial herbs and plants which have underground rhizomes, tubers, etc.

The group of Phanerogams falls into two divisions, the first containing only one class, the second two classes.

A. Gymnospermæ. The ovule is naked; that is to say, it is not enclosed in an ovary, but is attached to a carpellary leaf or simply to the axis of the flower. The endosperm is developed in the embryo-sac before fertilisation; the oosphere is situated within a special organ, the corpusculum.

Class VIII. *Gymnospermæ.*

B. Angiospermæ. The ovule is enclosed in an ovary; the endosperm is not formed in the embryo-sac before fertilisation, and the oosphere is formed by free cell-formation.

Class IX. *Monocotyledons.* The embryo has but one cotyledon, and the ripe seed usually contains much endosperm.

Class X. *Dicotyledons.* The embryo has two opposite cotyledons, and the endosperm is frequently all absorbed before the seed is ripe.

DIVISION A.

CLASS VIII.—GYMNOSPERMÆ.

The ovule is not enclosed in an ovary; it is attached either to an open carpel, or to the axis, no carpel being present. The endosperm is formed in the embryo-sac before fertilisation, and the oosphere is developed in a special organ, the corpusculum.

The flowers are always diclinous, frequently diœcious, and almost always without a perianth. The male flowers consist of a prolonged axis on which numerous stamens are inserted. These are sometimes peltate, like those scales of Equisetum which bear the sporangia, but sometimes they have a greater resemblance to an ordinary petiolate leaf. They bear on the inferior surface two or more separate pollen-sacs (Fig. 132 *A a*), which open longitudinally,

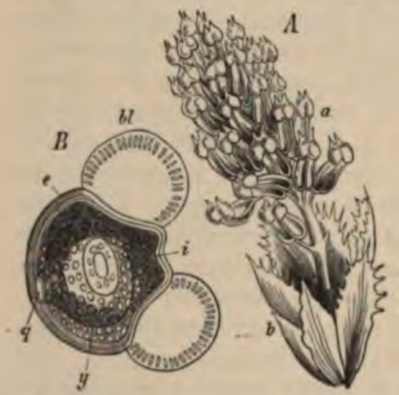


FIG. 132.—*A* Male flower of *Abies pectinata*; *b* bracts; *a* stamens. *B* Pollen-grain highly magnified; *e* extine with a bladder-like expansion (*bl*); *i* intine; *y* the included cells. (After Sachs.)

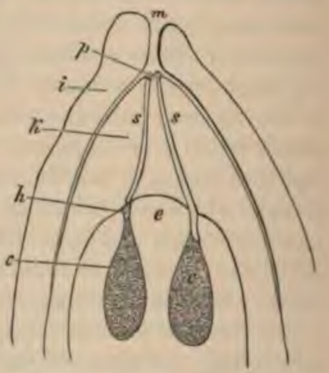


FIG. 133.—Process of fertilisation in Pinus (a magnified diagram): *m* micropyle; *i* integument; *k* nucellus; *c* the oosphere; *h* neck of the corpusculum; *e* endosperm filling the embryo-sac; *p* pollen-grains; *s* the tubes.

so as to allow the pollen-grains to escape. These always consist of at least two (Fig. 132 *B*), and often of several cells, from the largest of which the pollen-tube is developed. In the course of this process the extine is usually ruptured and shed, but in some rare cases, *e.g.*, in the Cycadeæ, it is pierced by the pollen-tube.

The female flowers are usually prolonged axes, which in some cases bear carpels upon which the ovules are inserted, and in others, bear the ovules directly, carpels not being present. The carpels are frequently closely packed around the ovules, but they do not form an ovary.

The ovule is commonly orthotropous, with a very short funicle and having but one integument. The nucellus is large and the embryo-sac is at some distance from the micropyle (Fig. 133 *e*); the sac becomes filled with endosperm in which, at the anterior end, several corpuscula are developed (Fig. 133 *c*). Each corpusculum consists of a neck (Fig. 133 *h*), which is formed of one or of a small number of small cells, and of a large central cell, the oosphere (Fig. 133 *c*). From the structure and arrangement of these organs it may be seen that the Gymnosperms occupy an intermediate position between the Phanerogams and the higher Cryptogams. The embryo-sac corresponds to the macrospore; in this case it gives rise to a prothallium (the endosperm) without becoming separated from the parent-plant; on this prothallium several archegonia (the corpuscula) are produced. The pollen-grains correspond to the microspores, but they do not here give rise to antherozoids. The pollen-grains are borne by the wind to the micropyle; they are conveyed through it by the fluid there secreted to the nucellus, and they penetrate its tissue by means of the pollen-tubes which they protrude; each tube makes its way through the neck of a corpusculum, coming into contact with the oosphere, which is thus fertilised (Fig. 133 *s*). The fertilised oosphere elongates downwards, forming a suspensor bearing the embryo at its inferior extremity.

The ripe seed always contains endosperm in the midst of which the embryo lies longitudinally, its root-end being turned towards the micropyle (Fig. 131 *I y*). The stem bears two or more cotyledons arranged in a whorl (Fig. 131 *c*).

The class contains the following three orders:

1. *Cycadeæ.* The trunk is rarely branched, or not branched at all; the leaves are large and much branched.

2. *Coniferæ.* The stems are much branched, the branching being axillary and monopodial; the leaves are very small and entire.

3. *Gnetaceæ.* The habit of these plants is various; they distinctly approach the Angiosperms in the character of their flowers.

Order 1. CYCADEÆ.

The stem is slightly branched or not at all; the leaves are large and branching.

The Cycadeæ are plants which, in many particulars, have affinities with the Ferns, while, on the other hand, in external appearance they resemble the Palms. The stem is tubercular or cylindrical, and thickly set with leaves. The leaves are of two kinds—some being scale-like, brown, and dry, closely covering the stem, the others being green, pinnate, and of a leathery consistency; these last are produced annually, or at a longer interval, and form a magnificent crown at the apex of the stem.

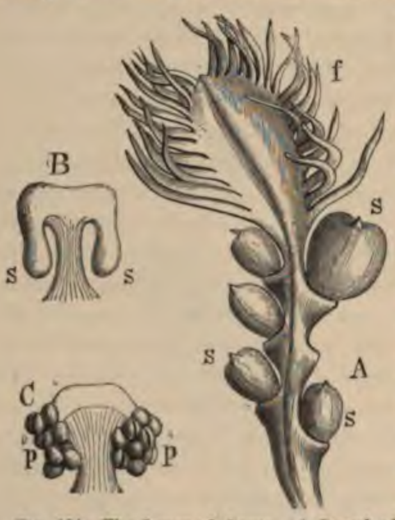


FIG. 134.—The flower of Cycas. *A* Carpel of *Cycas revoluta* (¼ nat. size); *f* pinnæ; *s* ovules. *B* Carpel of *Zamia muricata*, with two ovules (*s*). *C* Stamen of the same, with the anthers (*p*).

The flowers are produced terminally at the apex of the stem, the male and female flowers being borne by different individuals. The male flowers consist of an axis which bears peltate stamens, having the pollen-sacs on their inferior surfaces; they somewhat resemble the spikes of sporangia of Equisetum. The female flowers are for the most part cone-like; the axis bears numerous carpels; on the inner side of each carpel there are two orthotropous ovules (Fig. 134 *B*). In the genus Cycas the female flower is composed of a rosette of leaves, each of which is formed like the foliage leaves of the plant, only that it is much smaller and bears ovules in the place of the lower pinnæ (Fig. 134 *A*). In Cycas, too, the axis of the plant continues to grow after the production of the flower.

The ovules have an integument which becomes succulent at maturity, and they acquire a considerable size. Those of Cycas are as large as a plum even before fertilisation.

The embryo has two cotyledons which do not escape from the seed on germination.

The Cycadeæ are natives of tropical America; they occur—fewer in number—in South America and tropical Asia. *Cycas revoluta* and *circinalis*, *Zamia muricata* and *Dion edule* are often grown in hothouses.

Order 2. CONIFERÆ.

The stem branches extensively from the axils of the leaves, but not from all. The leaves are entire and relatively small.

This order includes the Pines and Firs which are abundant in temperate climates. A conspicuous feature in their habit is the regularity of the monopodial branching of the stem. In the structure of their tissues they exhibit affinity with the Dicotyledons; the trunk increases in thickness, as it does in the Dicotyledons, by means of a ring of cambium; the secondary wood, however, contains no vessels, but consists entirely of wood-cells (tracheïdes), the walls of which bear peculiar bordered pits (Fig. 42).

The male flower consists of an elongated axis covered with stamens of various forms, which bear two or more pollen-sacs on their inferior surfaces (Fig. 132 *A*).

The structure of the female flower differs considerably in the various families, and in some has not yet been accurately investigated.

The embryo has a conspicuous primary root which grows persistently, and two or more cotyledons which escape from the seed and unfold on germination (Fig. 131).

Sub-order 1. TAXINEÆ. The ovules are perfectly naked, there being no carpels. The flowers are always diœcious; the embryo has two cotyledons.

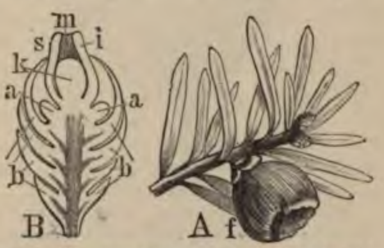


FIG. 135.—*Taxus baccata*. *A* The branch of a female tree with (*f*) fruit (nat. size). *B* Section of a female flower (× 20); *b* scale-like bracts which are still visible at the base of the fruit; *s* the apparently terminal ovule, with (*i*) the integument; *m* micropyle; *k* nucellus; *a a* the rudiment of the arillus, which subsequently grows up round the seed.

Taxus baccata is the Yew; the ovules occur singly at the end of very short branches (Fig. 135 *B*), which bear numerous bracts. The fertilised ovule during its maturation becomes surrounded by an arillus (Fig. 135 *A f*), which, when it is ripe, is red and fleshy. The leaves, which are spirally arranged, project on two sides from the stem, and are flat and linear, light green upon the under surface, but destitute of white stripes; by this the tree is at once distinguishable from the Silver Fir, which resembles it in habit. *Salisburya adiantifolia* (*Ginkgo biloba*), which grows in China and Japan, has broad wedge-shaped leaves, with palmate venation. Phyllocladus has flattened phylloid branches.

Sub-order 2. ARAUCARIACEÆ. Flowers usually monœcious. The female flower is the well-known cone of the Firs and Pines, consisting of an axis (Fig. 136 *B sp*) bearing scales (Fig. 136 *c*), arranged spirally or in whorls, which are the bracts. In the axil of each of these bracts there is a second scale, the carpellary scale, which usually bears two or more ovules(Fig. 136 *sk*). The relation of these two scales to each other has been explained in a variety of ways. The view here followed is, that the carpellary scale represents the axillary branch of the bract, consisting of an axis bearing a carpel which is fused with it, and which bears the ovules.

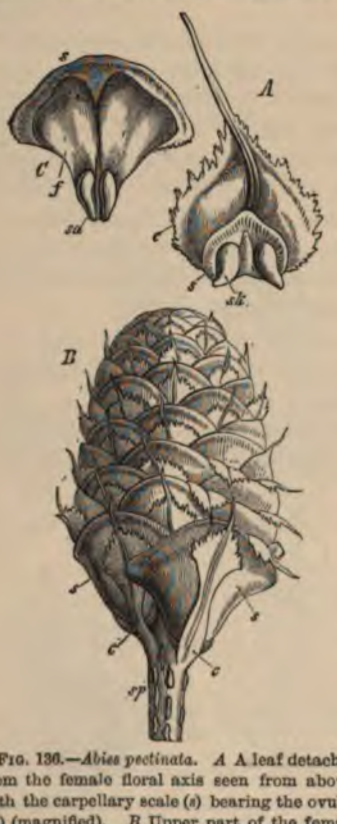


FIG. 136.—*Abies pectinata*. *A* A leaf detached from the female floral axis seen from above, with the carpellary scale (*s*) bearing the ovules (*sk*) (magnified). *B* Upper part of the female flower (or cone) in the mature state; *sp* floral axis or axis of the cone; *c* its leaves (bracts); *s* the largely-developed carpellary scales. *C* A ripe carpellary scale, with the two seeds (*sa*); *f* the wing of the seed (reduced).

In some genera (Pinus, Juniperus), the seed takes two years to come to maturity; in the first year, the pollen-tube penetrates only a short distance into the tissue of the nucellus, and it is not till the following year that it reaches the embryo-sac and fertilises the oosphere; the embryo at once begins to develope.

The embryo has from 2 to 15 cotyledons (Fig. 131 *c*).

This Sub-order may be divided into the following four families:

Fam. 1. *Abietineæ*. The carpellary scale is coherent with the bract only at the base; the micropyle of the ovule is directed downwards; the arrangement of the leaves and scales is spiral.

The flowers are monœcious: there are two ovules at the base of each carpellary scale; the ripe seed has winged appendages springing from the surface of the carpellary scale (Fig. 136 *C f*); the pollen-grains have usually vesicular expansions of the extine (Fig. 132 *B bl*) filled with air.

The genus Abies has flat carpellary scales; the seeds ripen in a single year; the leaves, which persist for several years, are arranged spirally only on the elongated shoots. In most species the persistently growing stem bears well-developed lateral branches in the axils of the leaves belonging to the upper portion of each year's growth, and less well-developed branches irregularly in the axils of leaves lower down. The secondary branches develope in the same manner; the development of branches of a higher order takes place especially on the two sides of the nearly horizontal primary branches.

The male flowers are developed in the axils of certain leaves of the shoot produced in the previous year.

In the sub-genus Abies, in its restricted sense, the Firs, the acicular leaves are flat, with two margins, and are marked with white streaks upon the under surface; the cone stands erect in the axil of a leaf borne by a shoot of the previous year, at some distance from its apex; when it is ripe, the bracts and carpellary scales fall off, together with the seeds, from the axis which persists for a time. To this genus belongs *Abies pectinata*, the Silver Fir, the emarginate leaves of which stand out in a comb-like manner from the branches. *A. cephalonica*, which grows in Greece, and *A. Pinsapo*, which grows in Spain, both have pointed leaves. In the sub-genus Picea, including the Spruces, the leaves are prismatic, with four angles; the cones are developed at the apex of the shoots of the previous year, become pendulous after fertilisation, and, after the shedding of the seed, drop off entire. To this group belongs *Abies excelsa*, the Norway Spruce. The sub-genus Tsuga (peculiar to North America) has cones like those of the Spruces and leaves like those of the Firs, and branches arranged in whorls, though this is not always evident, as in *A. canadensis* (the Hemlock Spruce) and *A. Douglasii*.

The cones of the genus Larix, the Larches, resemble those of Abies; the leaves persist through one season only; they are arranged spirally on the elongated branches, and in a fasciculate manner on the dwarf-shoots which are developed in the axils of the leaves of the elongated branches of the previous year; these dwarf-shoots grow but slightly every year, but they may be transformed into elongated branches. The male flowers, as also the cones, are situated at the apex of the dwarf-shoots. The branches are not arranged in whorls but irregularly. *L. europæa* belongs to the Alps and the Carpathians; other species are found in Siberia and in North America.

The genus Cedrus, the Cedars, differs from Larix in that the leaves, which are arranged in the same way, persist for more than one year, and in that the seed takes two years to ripen. *C. Libani* occurs in Asia Minor, and *C. Deodara* in the Himalayas.

In the genus Pinus, the Pines, the carpellary scales have a thickening at their free ends, presenting on the exterior a rhombic surface, the *apophysis*. The seed takes two years to ripen. The green leaves, which persist for several years, are borne in groups of two, three, or five, on dwarf-shoots which bear cataphyllary leaves at their bases, which do not elongate, and which are borne in the axils of the scaly leaves of the elongated branches of the same year. The primary branches are arranged in false whorls near the apex of the shoot of any one year, and the branches of a high order are also arranged in this manner. The male flowers take the places of the dwarf-shoots at the base of an elongated branch of the same year; they are closely packed. The cones take the places of the whorled branches near the apex of the elongated branches of the same year.

In the sub-genus Pinaster, each dwarf-shoot bears only two green leaves; the apophysis is rhombic, the seed is winged. To it belong ***Pinus sylvestris***, the Scotch Fir; the cones are borne upon short stalks and bend downwards; the winter-buds are rounded: *P. montana* occurs in the Alps; the stem is usually procumbent, but sometimes erect; the cones are sessile and are placed horizontally: *P. Laricio* occurs in southern Europe, and has pointed winter-buds: ***P. pinea*** is the Stone-Pine of the south of Europe; the seeds are large and edible, with small wings. The North American sub-genus Tæda differs from the preceding in that the dwarf-shoots bear three leaves. In the sub-genus Strobus, including ***Pinus Strobus***, the Weymouth Pine, the dwarf-shoots bear five leaves; the apophysis is semi-rhombic, and the seed is winged. The sub-genus Cembra, finally, has a large wingless seed, and its cones fall to pieces; to it belongs *Pinus Cembra*, the Siberian Stone-Pine, occurring in mountainous districts such as the Alps and Carpathians.

Fam. 2. *Araucarieæ.* The carpellary scale is completely fused with the bract; the micropyle of the ovule is directed downwards; the leaves and the scales of the cones are arranged spirally; the ovules are completely enclosed by the scales; they are trees with very regular branching; branches in whorls.

Araucaria imbricata occurs in Chili; *A. excelsa* on Norfolk Island. ***Dammara orientalis***, in the East Indies, furnishes the Dammar resin. In Cunninghamia each scale bears three ovules, whereas in Araucaria and Dammara it bears only one.

Fam. 3. *Taxodieæ.* The carpellary scale is completely fused with the bract; the micropyle of the ovule is directed upwards; leaves and scales arranged spirally.

Taxodium distichum, the Deciduous Cypress, grows in swamps in the United States. *Wellingtonia gigantea* (or Sequoia) is the Californian Pine, remarkable for its enormous size and for the great age which it attains. *Cryptomeria japonica* is an ornamental shrub.

Fam. 4. *Cupressineæ.* The carpellary scale is completely fused with the bract; the micropyle of the ovule is directed upwards; the leaves and scales are arranged in whorls.

The leaves are arranged in whorls of two or three, and at their bases are continuous with the cortex of the branches. The scales (consisting of the fused bract and carpellary scale) of the cone bear one or more ovules on their inner surface at the base. In *Juniperus communis* and allied species each scale bears only one ovule, placed somewhat to one side, on its inner surface; so that it appears as if the three ovules alternated with the three scales. The flowers are monœcious or diœcious. The embryo usually has only two cotyledons.

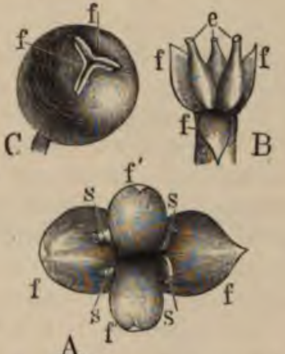


FIG. 137.—*A* A young cone of *Juniperus Sabina*, seen from above (mag.); *f f* the two inferior scales, each bearing two ovules (*s*); *f' f'* the two upper sterile scales. *B* Young cone of *Juniperus communis* after the removal of the bracts; *f f f* the three scales (the anterior one turned down); *e* the three ovules. *C* Ripe cone of the same plant; the three scales (*f*) can still be distinguished.

In Juniperus (diœcious) the scales of the cones become succulent when ripe and cohere to form a berry. In the sub-genus Oxycedrus (to which *J. communis*, the common Juniper, belongs), the leaves are arranged in whorls of three; in accordance with this the cone bears three scales. In the sub-genus Sabina (to which *J. Sabina*, *J. virginiana*, and others belong), the leaves are arranged in whorls of two; in these the cone bears two scales (Fig. 137 *A*), and each scale bears one or two ovules. *Thuja occidentalis*, from North America, is commonly cultivated. The scales of the cones, which bear each two ovules, become woody and the fruit opens like a capsule; the seed has a narrow wing. The decussate leaves project but little from the surface of the branch, and bear a protruding resin-receptacle. The ultimate shoots branch only in one plane, and thus come to resemble branched leaves. *Biota orientalis*, from China, is similar to the preceding, but the seed is not winged, and the linear resin-receptacles are imbedded in the leaves. *Cupressus sempervirens*, the Cypress, has peltate stalked scales on the cones, bearing numerous ovules. This is also the case in Chamæcyparis, to which many ornamental shrubs belong, but each scale bears only two ovules. In Callitris the cone is rounded, and is composed of four scales; the lower broad scales bear two or three ovules, whereas the upper ones bear only one or they are sterile.

Order 3. GNETACEÆ.

The Gnetaceæ differ from the Coniferæ in that the male flowers are provided with an investment which more or less resembles the perianth of Angiosperms.

Ephedra distachya is a shrub occurring in Southern Europe; it somewhat resembles an Equisetum, for it has long erect branches and small leaves arranged in whorls, and coherent so as to form sheaths at intervals round the stem. The flowers are diœcious. *Welwitschia mirabilis* is a remarkable plant peculiar to Western Africa; it has a very short, thick stem, somewhat resembling a very large beetroot, and two large foliage-leaves, in the axils of which dichotomously branched inflorescences are developed. Both the male and female flowers are borne in cones; they are monœcious.

DIVISION B.

ANGIOSPERMÆ.

The ovules are enclosed in an ovary. The endosperm is formed in the embryo-sac, after fertilisation, by free cell-formation.

The flowers are for the most part hermaphrodite. The axis of the inflorescence is usually expanded, forming a *receptacle* or *torus* on which the closely packed floral leaves are arranged either in whorls or in a spiral. Each of the three sets of organs—the perianth, the andrœcium, and the gynœcium—when the arrangement is spiral, forms one or more turns of the spiral; when the arrangement is whorled, each consists of one or more whorls.

The growth of the axis of the inflorescence (excepting in certain abnormal instances) terminates in the production of the uppermost series of floral leaves. Buds never occur in the axils of these leaves, except in the case of monstrosities. The portion of the axis below the flower is usually prolonged and is called the *peduncle*, it is commonly furnished with one or more bracteoles (*prophylla*). When the peduncle is very short or suppressed the flower is said to be *sessile*.

The *Perianth* is completely absent in comparatively few families, *e.g.*, Piperaceæ. In most it consists of two series of organs differing in their structure and texture; the outer, called the *calyx*, composed of the sepals, and the inner, called the *corolla*, composed of the petals; when this is the case it is said to be *biseriate*.. The *Sepals* are usually firm in structure, of a green colour, and small in size; the *Petals* are more delicate, and are white or coloured, *e.g.*, Rose, Geranium, Flax. In many cases one or other of these two series is wanting, although it is well developed in allied plants: thus the calyx is wanting in the Compositæ, and the corolla in Caltha and Daphne. In the latter case the calyx usually assumes the texture of the corolla and becomes petaloid. Other plants have a simple perianth, one, that is, which does not present any distinction of calyx and corolla, and which cannot be proved to represent either the one or the other, when it is spoken of simply as a perianth. It is usually sepaloid (Stinging Nettle), more rarely petaloid (Aristolochia). The individual leaves of the perianth may be either perfectly separate (*eleutheropetalous* or *polypetalous* corolla, *eleutherosepalous* or *polysepalous* calyx), *e.g.*, Ranunculus; or they may cohere from the base upwards, so as to form a longer or shorter tube, which divides at its upper end into as many teeth or lobes as there were originally leaves (*gamosepalous* calyx, *gamopetalous* corolla) (Fig. 138 *A B C c* and *B k*); *e.g.*, the Primrose and the Tobacco plant. In Dianthus (the Pink) the sepals alone are coherent, as also in Daphne (Fig. 138 *D*) where the corolla is absent. More rarely all the leaves of the perianth cohere to form one tube, *e.g.*, the Hyacinth and allied genera; the six lobes of the tube correspond to the three sepals and the three petals. The simple perianth also may consist of separate leaves (*eleutherophyllous* or *polyphyllous* perianth), *e.g.*, Amarantus, or the leaves may be coherent (*gamophyllous*), *e.g.*, Aristolochia.

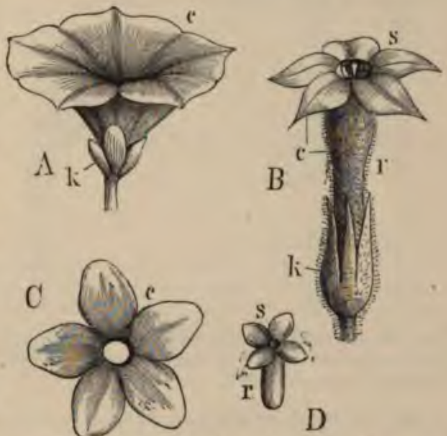


FIG. 138.—Coherent sepals and petals. *A* Flower of *Convolvulus arvensis*, with a funnel-shaped corolla (*c*); and a 5-partite calyx (*k*). *B Nicotiana Tabacum*, with a 5-cleft calyx (*k*); tubular corolla (*r*), with a distinct 5-toothed limb (*s*). *C* The rotate corolla of Sambucus. *D* Gamosepalous calyx of *Daphne Mezereum*; *r* the tube; *s* the limb.

The degree of division presented by gamophyllous perianths into teeth or lobes is indicated by the same terms which are used in describing the incision of the leaf-blade (page 12). The form of the gamopetalous corolla may be *campanulate*, as in the Campanula; *funnel-shaped* (or *infundibuliform*), as in the Bind-weed (Fig. 138 *A*); *rotate*, as in the Elder (Fig. 138 *c*). The upper and lower portions may frequently be distinguished, the lower as *the tube* (Fig. 138 *B r*), the upper expanded part as *the limb* (Fig. 138 *B s*). Other peculiarities of form are connected with the symmetry of the flower (page 194).

The petal frequently consists of two parts, the *claw* and the *limb*, as in the Pink (Fig. 139 *A B*). The *Corona* (paracorolla) in the Narcissus and Lychnis is formed by ligular outgrowths from the claws (Fig. 139 *B l*). Any segmentation of the petal, as in the Pink (Fig. 139 *A*) is unusual; emarginate or obcordate petals are more common. In many cases the petals have spur-shaped appendages (Violet), or they are prolonged at the base into tubes, as in Helleborus and Aconitum. This peculiarity is connected with the secretion of the nectar (page 194).

The *caliculus* or *epicalyx* is formed by leaves which grow close under the true calyx of the flower; such are the small leaves which alternate with the sepals in Potentilla (Fig. 139 *C a*) and in Malva. In some cases these leaves are the stipules of the sepals, in others they are bracts developed close beneath the calyx. Such an arrangement of leaves close beneath the flower, so that on a superficial view they seem to form part of it, is of frequent occurrence, as in *Anemone Hepatica*.

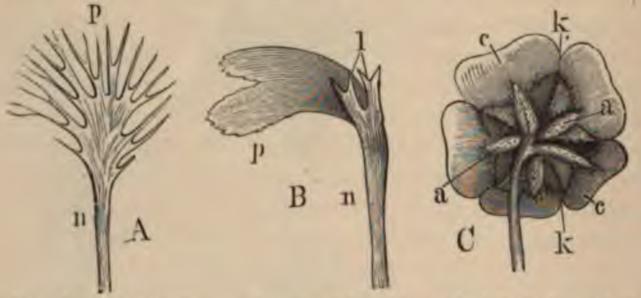


FIG. 139.—*A* Petal of *Dianthus superbus*, with (*n*) the claw and (*p*) the limb, much divided. *B* Petal of Lychnis; *n* claw; *p* limb; *l* ligula. *C* Flower of Potentilla, seen from below; *c* corolla; *k* calyx; *a* epicalyx.

The *Andrœcium* consists of the male organs of the flower, the stamens. Each stamen consists of two parts; a slender stalk called the *filament* (Fig. 140 *s*), and the organ which contains the pollen-sacs (Fig. 140 *D p*), known as the *anther* (Fig. 140 *a*). The anther consists of two longitudinal halves, each of which usually contains two pollen-sacs; these two halves are united by the upper portion of the filament which is known as the *connective* (Fig. 140 *c*). This is occasionally very narrow, so that the two halves of the anthers lie close together (Fig. 140 A_1 *a*); in this case it may be that the connective is not sharply marked off from the filament, and then the anther is simply attached to the upper end of the filament (*innate*); or it may be articulated as by a joint, so that the anther with the connective can oscillate on the apex of the filament (*versatile anther*, Fig. 140 A_2). But the connective is often broader, so that the two halves of the anther are widely separated (Fig. 140 *B*); it may be much elongated and very delicate, so that, with the filament, it forms a T-shaped body (Fig. 140 *C*); in this plant, the Sage, the further peculiarity is exhibited that one-half of the anther is abortive and is modified for another purpose. It is only rarely, as in Herb Paris, that the connective is prolonged beyond the anther into a point, or into a bristle, as in the Oleander; the two halves of the anther then appear to be placed laterally on the filament.

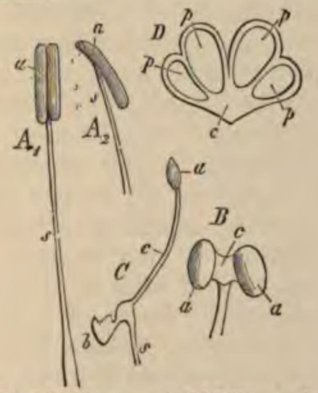


FIG. 140.—Stamen. A_1 Of Lilium; *s* filament; *a* the anthers. A_2 Side view. *B* Of Tilia; *c* connective. *C* Of Salvia; *b* is the half of the anther that has been modified. *D* Transverse section of the anther of Hypericum (mag.); *p* the 4 pollen-sacs; *c* connective.

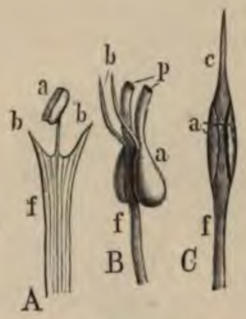


FIG. 141.—*A* Stamen of Allium. *B* Of *Vaccinium Myrtillus*. *C* Of *Paris quadrifolia* (mag.); *f* filament; *c* connective; *a* anthers; *b* appendages; *p* the pores by which the anther opens.

The filament is usually round and stalk-like, of a delicate coloured or colourless tissue; it is occasionally flattened; when it is very short the anthers are said to be *sessile*.

In some plants, *e.g.*, Allium (Fig. 141 *A*), the filament has appendages; in others, *e.g.*, Erica (Fig. 141 *B*) and Asclepiadeæ, the anthers themselves are furnished with appendages, such as spurs and so forth. In certain plants, as Ricinus and Hypericum, the stamens, that is to say the filaments, branch, either, like most leaves, in a plane perpendicular to the median plane, as in Myrtaceæ, or in various directions, as in Ricinus (Fig. 142); an anther is borne on each of the branches of the filament.

Somewhat similar in appearance, but essentially different in structure, are the coherent stamens of the Papilionaceæ and other plants. The stamens of each flower may be collected into a bundle, commonly into a tube, or into groups of two, three or more, when they are said to be *mono-*, *di-*, *tri-*, or *poly-adelphous*. The anthers and the upper portion of the filaments commonly remain free. The arrangement becomes highly complicated when the filaments are at the same time coherent and branched, as in Malvaceæ. In the Compositæ, *e.g.*, the Sunflower and Thistle, the filaments are free, but the anthers become coherent (*syngenesious*), though they are not originally united.

Besides these varieties of arrangement, it frequently occurs that the filaments adhere to other portions of the flower, particularly of the perianth, so that they—or when they are very short, the anthers—appear to be inserted not upon the axis of the flower, but upon the leaves of the perianth (*epipetalous* or *epiphyllous*). This condition is most frequently present when the petals themselves are connate and form a tubular corolla, *e.g.*, Primula. The adhesion of the stamens to the carpels is of rarer occurrence, *e.g.*, Orchidaceæ; the flower is then termed *gynandrous*. In many flowers it happens that certain filaments, occupying a definite position with regard to the other parts of the flower, are longer than the others; thus, of the six stamens of the Cruciferæ (*e.g.*, Rape and Cabbage), four are much longer than the other two; of the four stamens of the Labiatæ (*e.g.*, Lamium), two are longer than the other two. In the former case the stamens are said to be *tetradynamous*, in the latter *didynamous*.

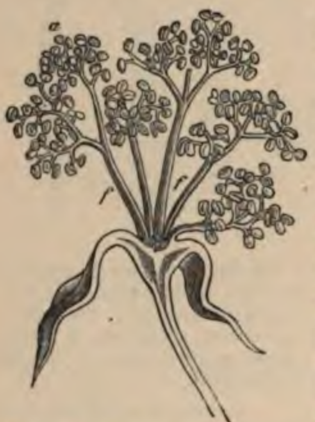


FIG 142.—Part of a male flower of *Ricinus communis* cut through lengthways; *f f* the basal portions of the compoundly-branched stamens; *a* the anthers. (After Sachs.)

Stamens which bear no anthers and which present to a certain extent a leafy appearance are called *staminodia;* they occur regularly in some flowers (*e.g.*, Canna). *Double flowers* are produced by the assumption of a petaloid appearance by the whole of the stamens—or the larger number of them.* In many flowers which have a spiral arrangement of their parts, *e.g.*, Nymphæa, there are intermediate forms between the petals and stamens, so that the passage from one to the other is gradual.

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* In other cases the "doubling" is the result of a multiplication of the petals, the andrœcium remaining unaltered, *e.g.*, Campanula. The so-called doubling of Compositæ resembles this in its external features only. This will be discussed when the Order is under consideration.

The *pollen-sacs* are contained in the anthers, two, commonly, in each half (Fig. 140 *D p*); more rarely there is only one, or there may be four. The *pollen* is shed by the dehiscence of the anthers, usually in considerable quantity. The mode of dehiscence of the anthers is indicated by their structure; some, as in Ericaceæ, open by a circular pore at the apex of each half of the anther, but most of them have a longitudinal slit on the inner side, *i.e.*, the side facing the centre of the flower (*introrse*), or on the outer side (*extrorse*).

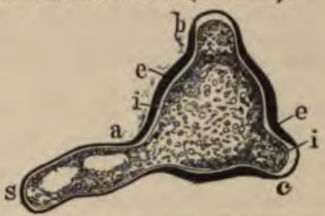


FIG. 143.—Pollen-grain of Epilobium (highly mag.) bearing a pollen-tube; *e* extine; *i* intine; *a b c* the three spots where the extine is thinner in anticipation of the formation of the pollen-tube (*s*), developed in this case at *a*.

When the pollen-grain reaches the stigma (see the next section), or if it is immersed in a solution of sugar, the intine, or inner coat of the grain, protrudes one or more long tubes, the *pollen-tubes* (Fig. 143 *s*). The spots at which the extine, or outer coat, is thus ruptured by the growing cell are usually indicated beforehand by some peculiarity of structure such as a special thinness, or a lid-like development of the extine, and are also definite in number (1, 2, 3, 4, 6 or more).

The pollen-grains of some Orchids and a few other plants never separate but remain united in masses (*pollinia*) corresponding to the several pollen-sacs.

The *Gynœcium* or *Pistil* is always the terminal structure of the flower, occupying the apex of the floral axis. Each of its constituent parts is called a *carpel*, and in the Angiosperms they form the *ovaries*, which are closed cavities containing the ovules. If in a flower where there are several carpels each of them closes by the cohesion of its margins, they form so many ovaries; the gynœcium is then said to be *apocarpous* (Fig. 144 *A*), *e.g.*, Ranunculus, Pæonia, and Butomus; if there is only one carpel (Fig. 144 *B*), the pistil is said to be apocarpous and *simple*; if several carpels in one flower cohere and form a single ovary (Fig. 144 *C*), the gynœcium is said to be *syncarpous*, *e.g.*, Poppy and Lily. Intermediate forms occur in that the carpels may cohere by their lower ends whilst their upper ends remain free (Fig. 144 *D*).

The ovary is said to be *monomerous* when it is formed of only one carpel (Fig. 145 *A*), the margins of which cohere on the side opposite to the midrib. The side along which the midrib runs is the dorsal surface (Fig. 145 *A r*); opposite to it is the line of cohesion, the ventral suture, which runs therefore on the ventral surface. The cavity thus enclosed (*loculus*) is not usually divided by dissepiments, but it is a simple cavity, as in the Vetch; such an ovary is said to be *unilocular*. False or spurious dissepiments, formed by growths on the inner surface, occur in some few instances, as in Astragalus.

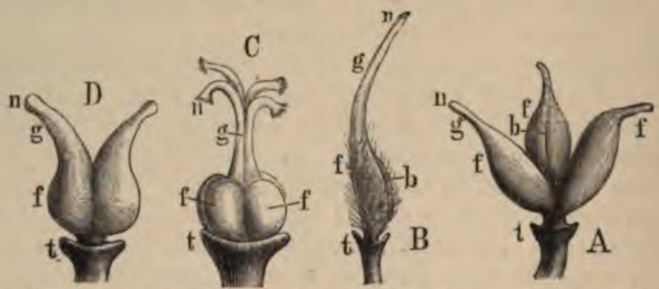


FIG. 144.—*A* Apocarpous gynœcium of Aconite. *B* Simple apocarpous pistil of Melilotus. *C* Tetramerous syncarpous pistil of Rhamnus. *D* Ovary of Saxifraga, formed of two carpels which diverge towards the top; *t* torus; *f* ovaries; *g* style; *n* stigma; *b* ventral suture.

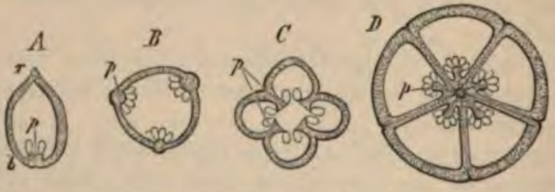


FIG. 145.—Transverse section of ovaries; p placenta. *A* Monomerous and unilocular; r dorsal suture; b ventral suture. *B* Polymerous and unilocular. *C* Polymerous and many-chambered, but unilocular. *D* Polymerous and multilocular.

When, on the other hand, several carpels cohere to form an ovary, it is *polymerous* (di-, tri-, or tetra-merous). This may be unilocular (Fig. 145 *B*) when the individual carpels cohere simply by their edges, without any portion of them projecting inwards; but if the margins project into the cavity so as to form longitudinal dissepiments, the ovary is *chambered* (Fig. 145 *C*), *e.g.*, Poppy; but since the chambers are open towards the middle, the ovary is still unilocular. When the margins form dissepiments which meet in the middle, the ovary is *multilocular;* sometimes the margins turn outwards again towards the circumference. In these cases the individual loculi are completely separated, but there are others in which the margins of the carpels do not extend so far towards the centre at the upper part as at the lower, but the two margins of each carpel simply cohere together above; consequently the lower part of the ovary is polymerous and multilocular, while the upper part is composed of a number of monomerous ovaries, *e.g.*, Saxifraga (Fig. 144 *D*). In all these cases the floral axis may grow up into the interior of the cavity of the ovary, and when the ovary is multilocular the axis may coalesce with the dissepiments.

False dissepiments may be formed in polymerous ovaries by ingrowths from the internal surface of the carpels; thus the ovary of the Boragineæ and Labiatæ is originally bilocular, but each loculus becomes divided into two by a false dissepiment, and when the fruit is ripe the four loculi separate completely.

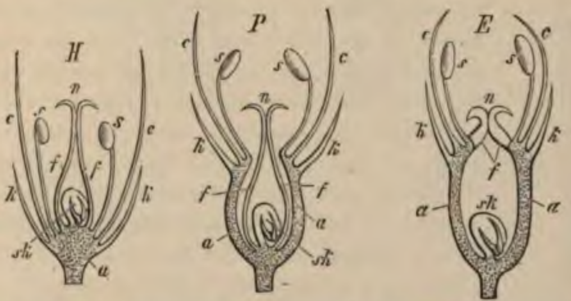


Fig. 146.—Diagram of, *H* hypogynous; *P* perigynous; *E* epigynous flowers; *a* axis; *k* calyx; *c* corolla; *s* stamens; *f* carpels; *n* stigma; *sk* ovule.

When the axis grows, as is usually the case, equally in all parts, the gynœcium, being nearest to its apex, is the uppermost part of the flower. When this is the case its insertion is above that of the stamens and perianth (Fig. 146 *H*), and the ovary is said to be *superior* and the flower *hypogynous,* as in Ranunculus, Papaver, Lilium, and Primula. But in a great number of plants the perianth and andrœcium are raised by the more vigorous growth of a lower portion of the axis (as represented by the outer portion of the torus) and stand on a circular rim surrounding the apex of the axis which lies at a lower level. Of this condition two different forms occur :—in the one, the carpels are inserted in the depression at the apex of the axis (Fig. 146 *P*), and there form one or more ovaries which are invested by the raised rim of the axis; they are quite free from it, primarily at least, though they may subsequently become adherent to it; in such cases, as in the Rose and Apple, the flower is said to be *perigynous:* in the other, the carpels spring from the upper rim of the cavity which is formed by the axis itself and simply cover it in at the top; such flowers are said to be *epigynous*, and the ovary to be *inferior*, *e.g.*, Gourds and Umbelliferæ (Fig. 146 *E*). Many transitional forms between these two extremes are found.

The inferior ovary of epigynous flowers is rarely monomerous, that is to say, the cavity formed by the axis is but seldom closed by one carpel only; it is commonly polymerous, but it may be either unilocular or multilocular; in the latter case, the margins of the carpels grow down along the internal surface of the cavity.

The *Style* (Figs. 144 and 147) is the slender prolongation of the upper part of the carpel: monomerous ovaries have but one style, polymerous ovaries have as many styles as there are carpels; these may cohere throughout their whole length or at their lower parts only, the upper parts remaining distinct; or they may remain quite free, and they may even branch. The style originally arises from the apex of the ovary, but it is frequently displaced forwards, by the vigorous development of the dorsal portion of the carpel, on to the inner side, so as to appear to be a prolongation of the floral axis. This is conspicuous in the Boraginaceæ and Labiatæ, where it is surrounded by the four rounded portions of the ovary which have been already mentioned (Fig. 222). The style is sometimes very short, and appears only as a constriction between the ovary and the stigma, as in the Poppy. In some rare cases it is hollow, but it is usually filled with a loose tissue, called *conducting tissue*, through which the pollen-tube can easily penetrate.

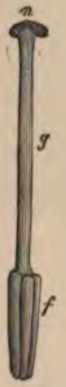


FIG. 147.—Gynœcium of the Lily; *f* ovary; *g* style; *n* stigma (nat. size).

The *Stigma* (Figs. 144 and 147 *n*) is the uppermost end of the carpel; it is distinguished by being covered with papillæ, or frequently with hairs, and by the secretion of a sticky fluid which retains the pollen-grains which fall upon it, and which promotes the development of the pollen-tubes. The stigma is often evidently distinct from the style, appearing as a lobed expansion; in other cases it seems to be merely a portion of the style at its end, or sometimes on its side. In Papaver it is a sessile disk-shaped expansion on the upper surface of the ovary; more rarely it is represented by bands of papillæ on the ovary itself, when it is said to be *pleurogynous*.

The *Ovules* are always enclosed in the cavity of the ovary either singly or in larger or smaller number. Usually they may be readily seen to be appendages of the carpels (Fig. 148 *A*, *B*, *C*, *E*), but in many cases they appear to be special organs developed in the cavity from the floral axis. However, from careful comparative examination, it seems that these apparently axial ovules are to be regarded as being originally appendages of the carpels, their position on the axis being merely the result of a more or less considerable displacement due to the coalescence of the carpels with the axis. That portion of the ovary which bears the ovules is called the *placenta*. In most cases it obviously belongs to the carpels, and even in cases of free central placentation (Fig. 148 *F*, *G*) it probably does, in part at least, also (Figs. 145 *p*, 148 *q*.)

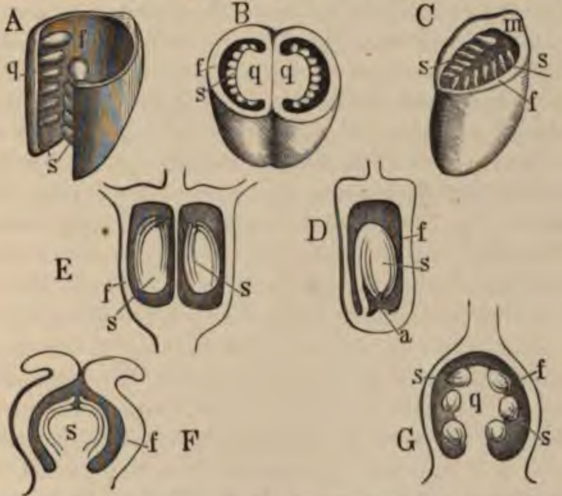


FIG. 148.—Diagram of the different modes of Placentation. *A* Carpel of Helleborus, opened along the ventral suture; *s* the ovules on (*q*) the marginal placenta. *B* Transverse section of the ovary of Nicotiana; *f* wall of the ovary; *q* placenta, largely developed by the union of the margins of the carpels (axile placentation). *C* Transverse section of the ovary of Butomus. The ovules are scattered over the whole of the inner surface, except the midrib, *m* (superficial placentation). *D* Longitudinal section of an ovary of one of the Compositæ; *f* the wall; the ovule (*s*) grows from the base by the side of the apex of the axis, *a*. *E* Longitudinal section of the ovary of one of the Umbelliferæ; in each chamber an ovule is suspended. *F* Longitudinal section of Rheum; a single ovule grows at the apex of the floral axis. *G* Longitudinal section of the ovary of one of the Primulaceæ; the ovules grow on a prolongation of the axis (free central placentation). Fig. 145 *B* represents parietal placentation.

The ovules borne by the carpels are usually *marginal*, that is to say, the placenta occupies a part or the whole of the longitudinal margin of each carpel, and bears either a single ovule or a single row (rarely more than one row) of ovules (Figs. 145 *p*, 148 *A q*). In polymerous ovaries the coherent margins frequently undergo a considerable thickening (Fig. 148 *B q*). The ovules are more rarely *superficial*, that is to say, borne upon the whole interior surface of the carpel, the midrib however usually remaining free (Fig. 148 *C*).

The apparently axial ovules are developed sometimes on the floor of the cavity of the ovary (Figs. 129 and 146), sometimes at the side of the apex of the axis, as in the Compositæ (Fig. 148 *D*), sometimes as prolongations of the axis, as in Piperaceæ and Polygoneæ (Fig. 148 *F*), sometimes on a placenta developed in the cavity of the ovary at the apex of the axis, as in Primulaceæ (Fig. 148 *G*).

The direction of the ovule varies; it may be *erect* (Fig. 148 *D*, *F*), or *suspended* (Fig. 148 *E*), or *horizontal* (Fig. 148 *A*), or *ascending*.

The *Nectary* is a glandular organ which secretes an odorous or usually a sweet fluid much sought after by insects. The nectaries are not distinct parts of the flower, but are developed on the other organs; thus in Rheum they occur at the base of the stamens; in the Umbelliferæ, as fleshy excrescences on the carpels; and in Citrus as an outgrowth of the floral axis below the carpels. When they have the form of an annular wall or a cushion, they are termed *discs* (*e.g.*, in Rhamnus). Sometimes, however, certain leaves of the flower are greatly altered in form and entirely diverted from their proper functions by the development of the nectaries; this happens in the Gesneraceæ to one of the five stamens, to the petals of Helleborus and Aquilegia, and to one of the petals of Viola, among many instances.

Relative Position and Number of the parts of the Flower. Symmetry of the Flower. The leaves forming the flower, like those borne by the vegetative part of the stem, are frequently arranged spirally, and the divergence is most commonly $\frac{2}{5}$, but higher divergences also occur, especially in the andrœcium, when numerous small organs are inserted upon an expanded axis (*e.g.*, Ranunculus). In the *spiral* or *acyclic* flower there is either no well-marked distinction of the various series, that is, the members of the calyx and of the corolla and the stamens are connected by intermediate forms (as in Nymphæa), or the various series are sharply defined, each series taking up one or more turns of the spiral. In the latter case, if the divergence is constant, the members of successive turns of the spiral are *superposed*, that is, they lie on the same radii drawn from the centre of the flower: this is well seen in many Urticaceæ, where the members of the perianth and the stamens are arranged in a continuous spiral with a divergence of $\frac{2}{5}$, each series taking up two turns of the spiral: here the five stamens are superposed upon the five leaves forming the perianth.

Many *cyclic* flowers—flowers, that is, the leaves of which are arranged in whorls—are very closely related to the latter form of acyclic flowers; this is shown by the fact that these two modes of arrangement are exhibited not only by the flowers of closely allied plants, but also by flowers of the same species. In this case, instead of there being five perianth leaves taking up two turns of a spiral with a divergence of $\frac{2}{5}$, four or six leaves are present, arranged in two whorls consisting of two or three leaves respectively. Since the same arrangement exists in the andrœcium, these two series of organs form four regularly alternating whorls, each consisting of two or three members. The two whorls of the perianth may be differentiated, as in most Angiosperms, into calyx and corolla, or they may together form a simple perianth, as in many Monochlamydeæ.

In other cyclic flowers the alternating whorls consist each of five members, and in these cases too, two of the whorls (calyx and corolla) belong to the perianth, the other two to the andrœcium. If instead of five, only four members are present in each, the calyx usually consists of two whorls each of two members, with which the whorl of petals alternates. When the perianth is differentiated into calyx and corolla and two whorls of stamens—consisting of the same number of members—are present, one whorl of stamens is opposite to or superposed on the sepals, and the other is superposed on the petals. Other less frequent modes of arrangement will be treated of in connection with the plants in which they occur.

When cyclic flowers consist of alternating whorls each containing the same number of members, they are said to be *eucyclic*. The number of members in a whorl is indicated by the expressions di-, tri-, tetra-, penta-merous, etc.; whorls containing the same number of members are said to be *isomerous*. When the members of a flower are arranged, some in whorls (usually in the perianth) and the others in a spiral (usually in the andrœcium), the flower is said to be *hemicyclic*.

These various arrangements, as in the case of the arrangement of the foliage leaves, are most clearly represented by means of diagrams. In a floral diagram, the calyx lies externally, and the gynœcium, as being the uppermost series or organs (even in epigynous flowers), lies most internally. In order to be able readily to distinguish the various series, symbols are used which recall some peculiarity of their form: thus the mid-rib of the sepals is indicated, and in the case of the stamens, the anthers.

If only such relations of position as can be observed in a flower are indicated in the diagram, a simple *empirical diagram* is the result. If, however, the results of the investigation of the development of the flower and of the comparison of it with others be borne in mind, a general plan of arrangement will be detected, and the individual peculiarities of arrangement, quite apart from any variation in the form of the organs, will be seen to be due either to the suppression of one or more whorls or of one or more members of a whorl, or, more rarely, to a multiplication of the whorls or of their members. If, however, the organs which are absent, but which should be typically present, be indicated in the empirical diagram by dots, it becomes a *theoretical diagram*. In this way it is possible to arrive at general types on which large numbers of flowers are constructed. Fig. 149, for instance, is the empirical diagram of the flower of the Lily, and it is at the same time the type on which the flower of Grasses (Fig. 150) is constructed in which certain organs are suppressed.

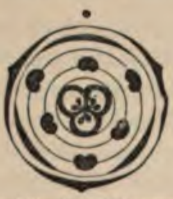


Fig. 149.—Floral Diagram of a Lily.

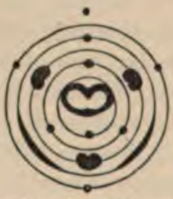


Fig. 150.—Floral Diagram of a Grass.

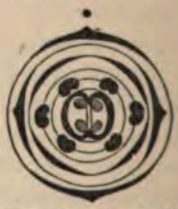


Fig. 151.—Floral Diagram of a Crucifer; the median stamens are doubled.

Under the head of multiplication of parts, *reduplication* or *pleiomery*—that is, the formation of two members in a whorl in place of one (Fig. 151)—must be especially considered. This is the result either of the branching of a member at an early stage, or of the original development of two members in the place of one.

The regular alternation of the whorls (especially when they consist of four or five members) in eucyclic flowers is often disturbed by a displacement of such a nature that the inner staminal whorl, which is normally superposed on the petals, and alternates with the sepals, comes to lie in the same plane as the outer whorl, or even externally to it (Fig. 152).

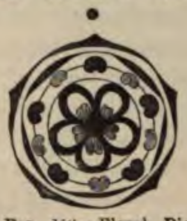


FIG. 152.—Floral Diagram of Dictamnus: the upper (internal) whorl of stamens (shaded) has been displaced, so that they lie between those of the lower (external) whorl: the carpels have also been displaced, so that they are superposed on the stamens of the inner whorl.

Hitherto nothing has been said as to the arrangement of the gynœcium in the flower, for it does not stand in such simple relations with the other series of members as they do to each other. Very frequently the number of carpels is smaller than that of the members of the other series, and in such a case their arrangement is quite irregular. If the gynœcium is isomerous with the calyx, corolla, and andrœcium, the carpels usually alternate with the inner whorl of stamens, as in most Monocotyledons (Fig. 149). When the above-mentioned displacement occurs in the andrœcium, the carpels sometimes alternate with the actually internal whorl of stamens, sometimes with the whorl which was primarily internal.

The number and the relations of the different parts of the flower may be indicated not by diagrams only, but also by formulæ, in which, as in the diagrams, for the sake of clearness, all the peculiarities of development are overlooked. Thus the diagram (Fig. 149) may be expressed by the formula $K3$, $C3$, $A3 + 3$, $G^{\underline{(3)}}$, which means that the calyx K, and the corolla C, each consist of a single whorl of three members, the andrœcium of two whorls each of three members, and the gynœcium of one whorl of three members, all in regular alternation. When one whorl is superposed on another, the superposition is indicated in the formula by a line | between the whorls. If the number of members in any whorl is variable, the letter n is used instead of a number. Thus, for instance, Kn, Cn, An + n, Gn is the theoretical formula of most Monocotyledons. The absence of a whorl is expressed by a cypher 0, and of individual members by the number of those actually present. Thus the formula for the flower of a Grass (Fig. 150) is $K0$, $C2$, $A3 + 0$, $G^{\underline{(2)}}$. The bracket in which the number of the carpels of the gynœcium G is here enclosed, indicates that the members thus bracketted are coherent. Superior and inferior ovaries are indicated by a stroke below or above the corresponding figure, and reduplication by the exponent 2; thus the diagram (Fig. 151) is represented by the formula $K2 + 2$,

$C \times 4$, $A2 + 2^2$, $G^{\underline{(2)}}$, the × after C indicating that the position of the petals is diagonal, *i.e.*, that the four petals alternate with the four sepals, as if the latter all belonged to the same whorl. Staminodia may be distinguished by a † before the figure. The position of the carpels in those cases in which the above-mentioned displacements of the stamens have occurred is indicated by a | placed before the number, which means that they are superposed on the petals. When the perianth is not differentiated into calyx and corolla, it is expressed by the letter P: thus, the formula for the flower of Asarum is $P3$ $A6 + 6$, $G_{\overline{(6)}}$.

The relations of position between the floral organs and the leaves which precede them yet remain to be considered. These can be most readily made out in the case of a lateral flower; of a flower, that is, the axis (peduncle) of which springs from the axil of one of the leaves of the main stem, and bears no leaves except the bracteoles and the floral organs themselves. A plane which passes through the flower, and also through the main stem and the median line of the subtending leaf (bract), is termed the *median plane* or *section* of the flower; the plane which cuts this one at right angles is termed the *lateral plane* or *section;* and the plane which bisects the angles made by the median and lateral planes is the *diagonal plane* or *section*. By means of these expressions the positions of the parts of a flower may be accurately indicated; thus, in speaking of the flower of the Cruciferæ (Fig. 151), the external whorl of sepals lies in the median plane, the carpels in the lateral, the petals in the diagonal. In all floral diagrams the position of the main axis should be indicated by a dot placed above the diagram; the bract, which would be of course exactly opposite to it, need not be indicated. The side towards the main axis is said to be *posterior*, and that towards the subtending leaf, *anterior*.

Many flowers, most Monocotyledons for instance, have only one bracteole (prophyllum), which is nearly always placed opposite to the bract, that is, posteriorly to the flower. When this is the case, a leaf of the trimerous calyx is placed anteriorly.

If two lateral bracteoles are present (usually indicated as α and β), as is the case in most Dicotyledons, the sepals, if the calyx is dimerous, are median; if the calyx is trimerous or pentamerous (whether it be whorled or spiral), one sepal is median and posterior.

It is obvious that such a flower as that represented in Fig. 153 can be divided into two symmetrical halves, resembling each other as an object and its reflected image, in one plane only, and that a vertical plane. In this case this plane coincides with the median plane of the flower.

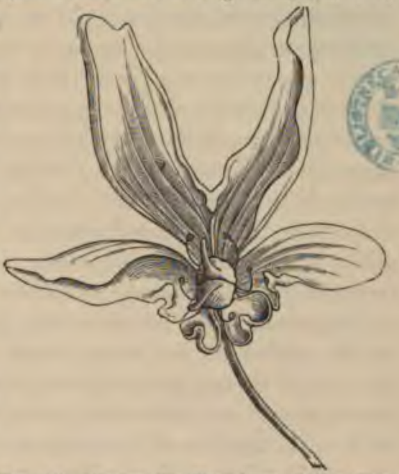


FIG. 153.—Flower of a Heracleum, with a zygomorphic Corolla (mag.).

Flowers which can be divided, like the one in Fig. 153, into two symmetrical halves in one plane only (which may or may not coincide with the median plane) are said to be *monosymmetrical* or *zygomorphic*, and in systematic works they are termed *irregular*. If a flower can be symmetrically divided in more than one plane, it is said to be *polysymmetrical*. In such flowers two cases may occur: in the one, the flower is *regular* or *actinomorphic*, that is, the halves produced by all possible sections are similar, or in other words, the flower may be divided into a number of similar sectors (see the diagrams, Figs. 149 and 152); in the other, the halves produced by one section are unlike those produced by another, and such flowers also are said to be zygomorphic or irregular. Those flowers are said to be *asymmetrical* which cannot be symmetrically divided by any section whatever.

These expressions apply as well to the relations of position and number as indicated in floral diagrams, as to the form of the perfect flower. It frequently happens that a flower which is more or less regular at its first appearance, subsequently becomes zygomorphic, as in Dictamnus and in the Leguminosæ and Labiatæ; spiral flowers also, the diagrams of which do not indicate any such condition, often assume a zygomorphic form, as in Aconitum. The zygomorphic symmetry of a flower is indicated in its floral formula by symbols; when the plane of symmetry coincides with the median plane the symbol $\downarrow$ is used, and when it coincides with the lateral plane the symbol $\rightarrow$.

Actinomorphic flowers sometimes occur abnormally, more especially near the extremity of the axis of inflorescence, in plants the flowers of which are normally zygomorphic. Such flowers are said to be *peloric*.

Pollination. It is essential, as a preliminary to fertilisation, that the pollen should be conveyed to the stigma. In a great number of hermaphrodite flowers, particularly such as are small and inconspicuous, the pollen is conveyed to the stigma of the same flower by very simple means; in some cases the pollen falls on to the stigma which lies at a lower level than the anthers, in others the close juxtaposition of the organs allows of its immediate transfer to the stigma so soon as the anthers open. In certain cases flowers are so modified as to ensure this *self-fertilisation;* instances of this are found in species of Viola, *Lamium amplexicaule*, *Oxalis Acetosella*, and others; these plants bear, in addition to their ordinary flowers, others which have an inconspicuous perianth which does not open; on account of their peculiar structure these flowers are said to be *cleistogamous.* In all these cases fertilisation is perfectly effected by the pollen of the same flower. It is, however, self-evident that, when flowers are diclinous, the pollen must be conveyed to the stigma of one flower from another; and it is now known that in a vast number of hermaphrodite flowers also, pollination is commonly effected by the transfer of pollen from one flower to another (*cross-fertilisation*). The conveyance of the pollen is effected in the case of a number of plants with inconspicuous flowers, such as the different Cereals, by the agency of the wind, when they are said to be *anemophilous;* but in the case of such flowers as are conspicuous by their size, colour, perfume, and by their copious secretion of honey, the insects which visit the flowers for the sake of the honey, as well as to gather pollen for food, perform this important function; these flowers are said to be *entomophilous.* In some of these cases it has been demonstrated that it is only the pollen of other flowers which can effect fertilisation, that the pollen of the flower itself is useless, or even injurious, and that consequently cross-fertilisation is indispensable. In other cases the pollen of the same flower, though not absolutely useless, has far less fertilising power than that of another flower; under these circumstances cross-fertilisation is advantageous. In other cases again, the pollen of the flower itself has as powerful a fertilising effect as the pollen of other flowers, but the superiority of cross-fertilisation is shown by the greater vigour of the progeny which are the issue of the crossing of two individuals.

In those flowers to which cross-fertilisation is indispensable or at least important, the most various contrivances are exhibited for the purpose of hindering or limiting self-fertilisation on the one hand,

and on the other of facilitating cross-fertilisation, or finally, in default of cross-fertilisation, of ensuring ultimate self-fertilisation; this last, of course, only in those cases in which the pollen of the flower itself is capable of fertilising it; for it is evident that self-fertilisation, even if not very advantageous, is at any rate of some use to the plant.

Among the contrivances for the prevention of self-fertilisation, one of the simplest is the arrangement of the anthers and stigma in such positions that the pollen cannot possibly reach the stigma of the same flower, *e.g.*, Aristolochia (Fig. 154), or secondly, the abortion of all the male organs in some flowers and of all the female organs in others; in such flowers the organs in question are present, but they are not functional. This is an approach to the diclinous condition; it occurs in the Tiger-lily, in which the anthers are commonly abortive in some flowers and the ovaries in others. Thirdly, *dichogamy* frequently occurs, that is, that the stigmas and stamens attain their functional activity at different times; flowers in which this occurs are either *protandrous*, that is, the anthers are first developed and have already shed their pollen when the stigma of the same flower is capable of receiving it, or they are *protogynous*, that is, the stigma is fully developed before the anthers of the same flower are ready to shed their pollen: in the latter case self-fertilisation is obviously only excluded if the stigma is withered before the pollen is shed; there are, however, protogynous flowers in which the stigma remains fresh for a long time and which may be fertilised by their own pollen. As examples of protandrous flowers, those of the Umbelliferæ, and most of the Compositæ, Lobeliaceæ, and Campanulaceæ may be mentioned; and of protogynous flowers, Aristolochia, Arum, *Scrophularia nodosa*, and some species of Plantago, but this condition is less common than the preceding.

Among the contrivances which lead to the cross-fertilisation of flowers by the agency of insects, the means of tempting insects to visit the flowers, such as bright colours, odours, and the secretion of honey, must be first mentioned. The peculiar marking of the flower serves in many cases the purpose of guiding insects to the nectary. The form of the flower, the situation of the honey, the position of the stamens, and their relation to the other parts of the flower, particularly to the stigma, the relative development in point of time of the different parts, all these circumstances combine and co-operate to secure cross-fertilisation, and sometimes to allow of the visits of particular insects only, as, for instance, of butterflies with long proboscES, though there are also cases in which the insects must occasionally convey the pollen to the stigma of the same flower. A simple arrangement of this kind, known as *heterostylism* or *dimorphism*, and which occurs in the Primulaceæ, Pulmonarieæ, and others, may be mentioned here. These plants have two kinds of flowers; in one form the stamens are short and the style much longer, so that the stigma projects above the anthers; in the other form, on the contrary, the anthers are on long filaments above the stigma, and they are so constructed that the anthers of one form stand on the same level as the stigma of the other (Fig. 226). From the position of the nectary, and the form of the rest of the flower, an insect visiting it is obliged to take up the same position at each visit; consequently after it has visited a flower of the one kind, when it visits a flower of the other kind, it touches the stigma of the latter with the same part of its body with which in the first flower it brushed the anthers, and thus the pollen which it carried away with it from the anthers of the one flower is transferred to the stigma of the other. Observations made by artificially transporting the pollen have shown that fertilisation is most complete when the pollen of stamens of a certain length is conveyed to the stigma of a style of the same length. The same is the case with *trimorphic* plants, *e.g.*, Oxalis: in these, three forms of flowers occur with three different lengths of styles and stamens.

As examples of more complicated contrivances for the purpose of securing cross-fertilisation, Aristolochia and Epipactis may be described.

The flower of *Aristolochia Clematitis* (Fig. 154) is protogynous; insects can penetrate without difficulty down the tube of the perianth, which is furnished on its internal aspect with hairs which point downwards, and they thus convey the pollen they have brought with them from other flowers, to the stigma; the hairs, however, prevent their return. When the pollen has reached the stigma, its lobes (Fig. 154 *A* and *B n*) spring upwards, and thus the anthers, which now begin to open, are made accessible to the insects; these, in their efforts to escape (Fig. 154 *l*), creep round the anthers, and some of the pollen adheres to them; by this time the hairs in the tube have withered, and the insect escapes, dusted over with pollen which, in spite of experience, it proceeds to convey in like manner to another flower. Those flowers which are ready for fertilisation have an erect position, and the tube of the perianth is open above so that the insect can readily enter; after fertilisation the peduncle bends downwards and the tube is closed by the broad lobe of the perianth, so that it is impossible for insects to enter flowers which have been fertilised.

In the flower of Epipactis (one of the Orchidaceæ), the anther is situated above the stigma and does not shed its pollen in isolated grains; but when a certain sticky portion of the stigma, known as the *rostellum* (Fig. 155 *h*), is touched, the entire pollen-sacs, together with the rostellum itself, are carried away. The insect creeps into the flower to obtain the honey which is secreted in the cavity of one of the leaves of the perianth, the *labellum* (Fig. 155 *l*), and, as

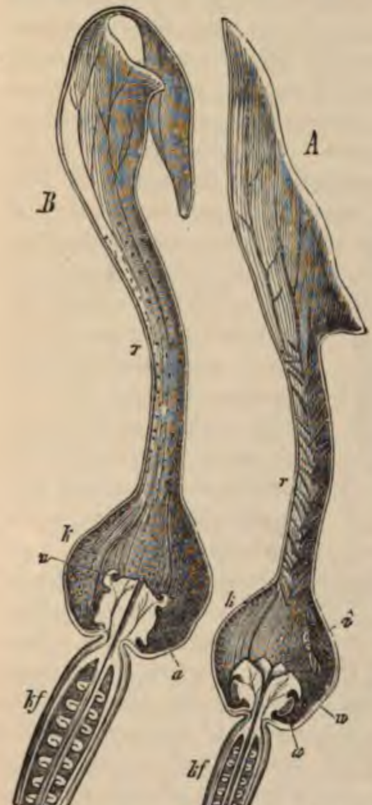


FIG. 154.—Flower of Aristolochia. *A* Before, and *B* after fertilisation; *r* the tube of the perianth; *k* the cavity below; *n* stigma; *a* anthers; *l* an insect; *kf* ovary. (After Sachs.)

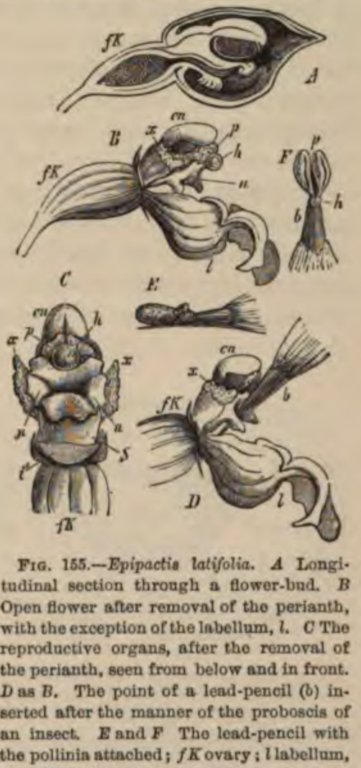


FIG. 155.—*Epipactis latifolia*. *A* Longitudinal section through a flower-bud. *B* Open flower after removal of the perianth, with the exception of the labellum, *l*. *C* The reproductive organs, after the removal of the perianth, seen from below and in front. *D* as *B*. The point of a lead-pencil (*b*) inserted after the manner of the proboscis of an insect. *E* and *F* The lead-pencil with the pollinia attached; *fK* ovary; *l* labellum, its sac-like depression serving as a nectary; *n* the broad stigma; *cn* the connective of the single fertile anther; *p* pollinia; *h* the rostellum; *x x* the two lateral gland-like staminodes; *i* place where the labellum has been cut off; *s* the columnar style. (After Sachs.)

it withdraws from the flower, it carries away the rostellum with the pollen-masses (*pollinia*). (In Fig. 155 the point of a pencil *b* has been introduced into the flower and the rostellum has adhered to it.) The insect, on entering the next flower, deposits the pollen upon the stigma.

In the course of frequent cross-fertilisation it is inevitable that the pollen of other species of plants should be applied to the stigma, but while the pollen of plants of very different species is wholly without effect, that of nearly allied species, particularly those belonging to the same genus in certain groups, has a fertilising effect; the result of such fertilisation is *hybridisation*, that is, the development of a plant which combines the characters of both parents to a certain extent, and which is known as a *bastard* or *hybrid*. Hybrids are for the most part sterile among themselves, but are often fertile when crossed again with a plant of either of the parent-species or of some allied species. While hybrids are produced with great ease in certain genera, as Salix and Cirsium, in others the artificial production of hybrids has never yet been found possible even between very closely allied species, as the Apple and Pear.

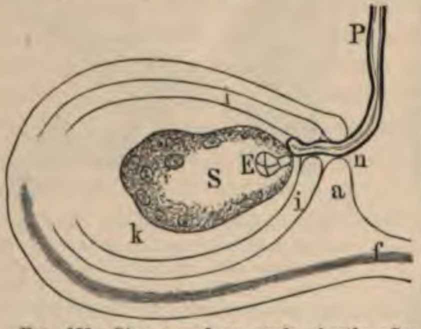


FIG. 156.—Diagram of an ovule shortly after fertilisation: *a* outer, and *i* inner integument; *f* funicle; *k* nucellus. *S* Embryo-sac in which *E* is the embryo developed from the fertilised oosphere. The sac also contains the endosperm-cells which are being formed by free cell-formation. *P* The pollen-tube, passing through the micropyle, *n*.

Fertilisation. After reaching the stigma the pollen-grains protrude the pollen-tubes which penetrate through the tissue of the style into the cavity of the ovary, and through the micropyle of each ovule to its nucellus (Fig. 156 *P n*). The time required by the pollen-tube for this process depends partly on its distance from the ovule and partly on the specific peculiarities of the plant; thus the pollen-tube of the Crocus takes only from one to three days to traverse the style which is from five to ten centimetres in length; but in the Orchids, where the length of the style varies from two to three millimetres, several days, weeks, or even months are needed, and it is during this process that the ovules are formed in the ovary.

In the Angiosperms the embryo-sac always lies at the anterior end of the nucellus, and it sometimes projects from the micropyle. It usually contains three cells at its posterior and three at its anterior end; the former are the *antipodal* cells, the latter are the *oosphere* with its two sister-cells the *synergidæ*. The oosphere becomes fertilised, and, in consequence of fertilisation, it becomes surrounded by a cell-wall, and elongates to form the *suspensor*, at the posterior end of which the embryo is developed (Fig. 156 *E*). Meanwhile the rest of the sac becomes filled with *endosperm;* this is usually first formed by free cell-formation, but in many cases it arises by the division of the embryo-sac. Thus the ovule becomes converted into the seed.

In the endosperm the nutritious substances which will be needed by the young plant when it germinates, are stored up. In many seeds the whole or the greater part of the endosperm is absorbed by the growing embryo; in that case the nutritious substances are deposited either in the persistent and increasing tissue of the nucellus (as in Canna and Piper, Fig. 157 *B P*), which is called the *perisperm*, or in the germ itself, in its *cotyledons*, which attain a considerable size (as in Bean, Horse-chestnut, and Almond, Fig. 157 *C*).

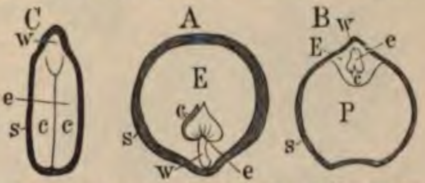


FIG. 157.—Sections of ripe seeds. *A* *Nux vomica*, showing *E* endosperm. *B* Piper, showing both endosperm, *E* and perisperm, *P*. *C* Almond, devoid of endosperm; *s* the testa; *e* embryo; *w* its radicle; *c c* its cotyledons.

The Fruit. The effect of fertilisation is not manifested only in the formation of the embryo from the oosphere and of the seed from the ovule; but it extends to the whole of the gynœcium, and occasionally even to other parts of the flower.

The word fruit, in its strictest sense, means the whole product of the development of the gynœcium as a result of fertilisation. If other parts of the flower take part in the formation of the organ which is formed in consequence of fertilisation, and which contains the seed (of what, in short, is commonly called the fruit), it is termed a *spurious fruit*. The apple, for instance, is such a spurious fruit, for the outer fleshy part belongs to that part of the axis of the perigynous flower which surrounds the ovaries and which still bears the sepals (Fig. 245 *D*). What are called the pips of the apple are the seeds. This kind of spurious fruit is termed a *pome*. The strawberry also is a spurious fruit: in it the receptacle, which belongs of course to the axis, developes largely and becomes fleshy and bears the true fruits (achenes) in the form of small hard grains. The fig is another example of a spurious fruit (Fig. 194); it is in fact a fleshy receptacle (*i.e.*, an axis) which bears a multitude of distinct flowers situated inside the cavity of the receptacle, and the individual fruits appear as hard grains; such a fruit is termed a *syconus*. Again, when the ovaries and floral envelopes of closely crowded flowers, as in the Mulberry and the Pine-apple, become succulent, a kind of spurious fruit is formed which is termed a *sorosis*.

In other cases, a husk, called the *cupula* is formed, which contributes to the formation of a spurious fruit: this is formed of leaves and is not developed until after fertilisation; it may surround either a solitary distinct fruit, like the acorn-cup (Fig. 211), or several distinct fruits, like the four-valved spiky husk of the Beech-tree or the prickly husk of the edible Chestnut.

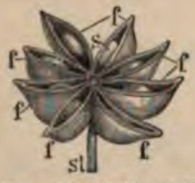


FIG. 158.—Fruit of *Illicium anisatum*: *st* peduncle; *ff* the separate fruits, each with a seed (*s*) forming an apocarpous fructification.

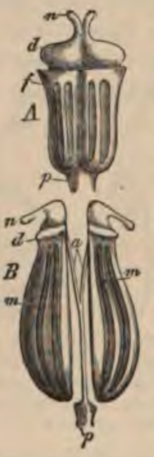


FIG. 159.—*Carum Carui*, one of the Umbelliferæ. *A* Ovary of the flower (*f*). *B* Ripe fruit which has divided into two mericarps (*m*), a portion of the median wall (*a*) forms the carpophore.

When the fruit consists of one or more monomerous ovaries, it is said to be *apocarpous*: examples of this occur in Ranunculus, in the Raspberry, where the individual ovaries are succulent, and in the Star-anise (Fig. 158). The individual fruits may be developed in very different ways; they may be dehiscent or indehiscent, dry or succulent.

When the fruit consists of a single polymerous ovary, it is said to be *syncarpous*. When the loculi of such a fruit separate from each other during the process of ripening, so that it ultimately appears as if a number of distinct fruits were present, it is termed a *schizocarp*; when two only are present, each of these is termed a *mericarp*, as in the Umbelliferæ (Fig. 159); in the Geraniaceæ, where there are several distinct fruits, each is termed a *coccus*; and in the Maple each fruit is winged, and is termed a *samara*. The individual cocci are always indehiscent.

In various multilocular ovaries only one loculus becomes fully developed and bears seeds, as in Valerian and the Oak; the others are abortive. It happens in rare cases that the fruit becomes perfectly formed without any development of seed or embryo, as in a particular seedless variety of Grape.

In all true fruits the wall of the ovary forms the *pericarp* or rind; this usually consists of three distinct layers; the external layer is the *epicarp*, the middle the *mesocarp*, and the innermost the *endocarp*. The following varieties of true fruits have been distinguished by the peculiarities of these three layers of their walls—whether they are dry or succulent, hard or soft,—and by the mode in which the fruit opens to allow the seed to escape.

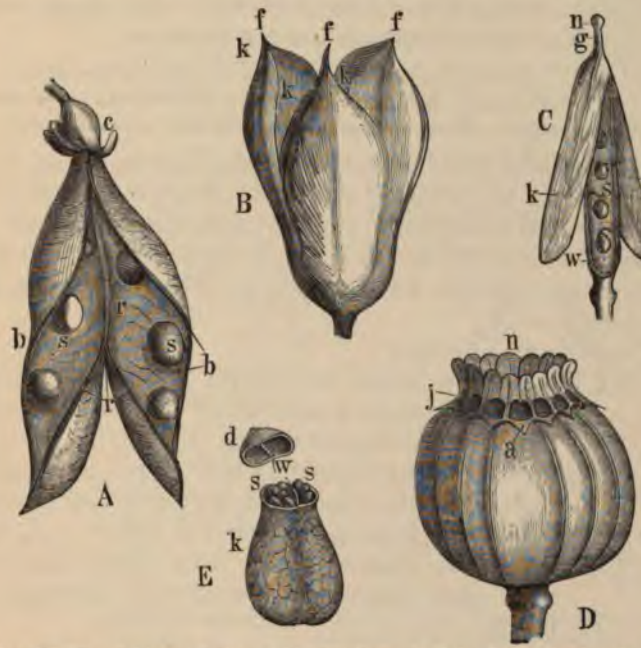


FIG. 160.—Dry dehiscent fruits. *A* The pod (legume) of the Pea; *r* the dorsal suture; *b* the ventral; *c* calyx; *s* seeds. *B* Septicidal capsule of *Colchicum autumnale*: *f f f* the three separating carpels. *C* Siliqua of Brassica; *k* the valves; *w* the dissepiment and placentæ (replum); *s* seeds; *g* style; *n* stigma. *D* Capsule, opening by pores, of *Papaver somniferum*, the Poppy; *n* stigma; *j* the pores which open by the removal of the valves (*a*). *E* Pyxidium of Hyoscyamus; *d* the lid; *w* the dissepiment; *s* seeds.

A. DRY FRUITS. The pericarp is woody or coriaceous; the sap has usually disappeared from all the cells.

I. *Dry Indehiscent Fruits.* The pericarp does not rupture, but encloses the seed until germination; the testa is usually thin and frequently coalescent with the pericarp.

(1) One-seeded fruits:

(*a*) The *nut* (*glans*), *e.g.*, hazel-nut (but not the walnut); the dry pericarp is hard and sclerenchymatous.

(*b*) The *achene* (superior): the pericarp is thin and coriaceous; *e.g.*, the Rose and the Buttercup. The similar fruit of the Compositæ is a *cypsela* (inferior).

The fruit of Grasses, termed a *caryopsis*, is very similar to the achene; it differs from it in that the testa and the pericarp closely adhere, whereas in the achene they are not adherent.

(2) Many-seeded fruits (*schizocarps*): these commonly split into one-seeded fruits, which usually enclose the solitary seeds until germination, *e.g.*, the Umbelliferæ (Fig. 159), Geraniaceæ and Maple.

II. *Dry Dehiscent Fruits.* The pericarp ruptures and allows the seeds to escape; the testa is usually firm and thick; they are commonly many-seeded.

(1) *Dehiscence longitudinal.*

(*a*) The *follicle*, consisting of a single carpel which opens along the ventral suture, where also the seeds are borne, *e.g.*, Pæonia and Illicium (Fig. 158).

(*b*) The *legume* or *pod* likewise consists of but one carpel which opens along both the dorsal and ventral sutures (Fig. 160 *A*, transverse section Fig. 145 *A*): *e.g.*, the Vetch, Pea, Bean, and many other Leguminosæ; in some cases (Astragalus) a spurious dissepiment occurs.

The *lomentum* is a modification of the legume; it is constricted between the seeds, and it is either indehiscent or it breaks across, when ripe, at the constricted parts. It occurs in the Hedysareæ.

(*c*) The *siliqua* consists of two carpels. The two carpels when ripe separate from the base upwards into two valves, leaving the spurious dissepiment (*replum*) which remains attached to the apex of the peduncle, and to the margins of which the parietal placentæ are attached; *e.g.*, Rape, Mustard, and most of the Cruciferæ (Fig. 160 *C*).

When the siliqua is short and broad, it is termed a *silicula*, as in Thlaspi and Capsella. In some cases, as in the Radish, the siliqua is jointed and indehiscent, breaking transversely into one-seeded portions. It resembles the lomentum, and is therefore said to be *lomentaceous*.

(*d*) The *capsule* is derived from a polymerous ovary which may be uni- or multilocular; it splits into two or more valves, either for a short distance only from the apex downwards, or down to the very base (Fig. 160 *B*). If the carpels become separated from each other, and in the case of multilocular ovaries this involves the splitting of the dissepiments (Fig. 161 *A*), the dehiscence is said to be *septicidal;* if, on the other hand, each carpel splits along its dorsal suture, the dehiscence is said to be *loculicidal* (Fig. 161 *B*). In multilocular ovaries the dissepiments may be persistent and remain either attached to the middle of the valves (Fig. 161 *B*), or united into a column which is free from the valves; in the latter case the dehiscence is said to be *septifragal* (Fig. 161 *C*).

The capsule is usually superior, but sometimes, as in Iridaceæ and Campanulaceæ, it is inferior; a special term, *diplotegium*, is applied to the inferior capsule by some authors.

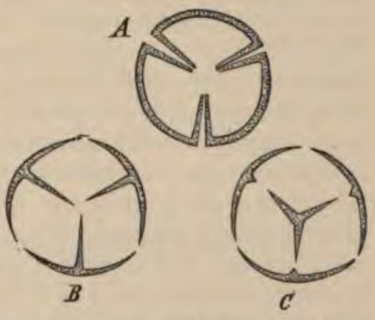


FIG. 161.—Diagrammatic sections of dehiscent capsules. *A* Septicidal, *B* loculicidal, *C* septifragal dehiscence.

(2) The form of capsule known as a *pyxidium* has a transverse dehiscence, *e.g.*, in Plantago, Anagallis, Hyoscyamus (Fig. 160 *E*); the upper part falls off like a lid.

(3) The *porous capsule, e.g.*, the Poppy (Fig. 160 *D*), sheds its seeds through small holes arising from the removal of small portions of the wall in certain spots.

B. SUCCULENT FRUITS. In these the pericarp (or at least some layers of it) retains its sap until it is ripe, and usually becomes fleshy at that stage; it is indehiscent.

(1) The *drupe* (Fig. 162), *e.g.*, the Plum, Cherry, and Walnut.

The most internal layer, the endocarp, is very hard and sclerenchymatous (Fig. 162 *E*), and encloses the seed until germination; the mesocarp is generally succulent, and the epicarp is a delicate membrane.

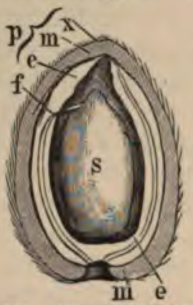


FIG. 162.—Longitudinal section of the drupe of the Almond: *s* the seed attached by the funicle (*f*); the hard endocarp; *m* the mesocarp; and *x* the epicarp—these constitute the pericarp (p).

(2) The *berry* (*bacca*); the endocarp is soft and juicy as well as the mesocarp, so that the seeds are imbedded in the pericarp: there may be one seed only, as in the Date, or many, as in the Gourd, Currant, and Grape: the fruit may have one loculus, as in the Grape and the Gourd, or several loculi, as in the Orange; and further, it may be superior, as in the Grape, Orange, and Lemon, or inferior, as in the Currant, the Gooseberry, and the Gourd.

The seeds of dehiscent fruits are usually provided with various contrivances to ensure their dispersion; in the case of indehiscent fruits, the fruit itself is thus provided: of this nature are the wing-like appendages of the fruit of the Maple and of the seeds of many Caryophyllaceous plants, the hairs upon the fruit of the Compositæ, and upon the seeds of the Cotton, the Willow, and the Poplar. The coats of many fruits and seeds have layers of cells which become extremely mucilaginous, *e.g.*, the Quince, the Flax (linseed), and the Plantain. The fruits of Geranium and allied genera have long beaks, by means of which they bury themselves in the soil.

Some seeds begin to germinate as soon as they are shed, but for the most part a period of rest is requisite; if this is too much prolonged, they lose their germinating power.

The *Inflorescence.* It is only in comparatively few plants that the first or main axis terminates in a flower; such plants are said to be *uniaxial:* it is not usually till the second or third branch, or one of even a higher order is developed, that a flower is produced; such plants are said to be *bi-*, *tri-*, or *poly-axial.*

The floral axis of Angiosperms frequently forms an elaborate branch-system which is usually sharply defined from the vegetative part of the plant, and which bears no leafy structures beyond those of the flower except bracts. This is known as the *inflorescence.*

In the inflorescence, as usually in all parts of Angiosperms, the branching is almost always monopodial and axillary. Some apparent exceptions may be easily reduced to this type; thus, in the racemes of most of the Cruciferæ the bracts at the bases of the individual pedicels are abortive, and the same occurs in many of the Compositæ; in the Solanaceæ and Boragineæ the bract often undergoes displacement, so that it appears to be inserted laterally upon the axillary shoot; on the other hand, it sometimes occurs that the axillary shoot is for some distance adherent to the main shoot.

A long flower-stalk with no leaves or with only a few small bracts, which bears at its upper end a crowded or a sharply defined inflorescence, is called a *scape*.

In accordance with the principles of branching already laid down on page 20, the different forms of inflorescence may be classified as follows:

A. *Racemose inflorescences:* consisting of a main axis or rachis bearing a number of lateral branches which have been developed in acropetal succession; the lateral shoots do not usually grow longer than that portion of the main axis which lies above their insertion. It is immaterial whether or not the main axis terminates in a flower. If the lateral shoots of the first order—*i.e.*, those which spring directly from the main axis of the inflorescence—terminate in a flower without any further ramification, the inflorescence is said to be *simple*, but if they branch it is said to be *compound*.

I. *Simple racemose inflorescences:*

(α) *With an elongated axis:* the lateral shoots, which are the pedicels, spring from the axis at some distance from each other. The three following forms may be distinguished:

(1) The *spike*, in which the flowers are sessile on the floral axis, or have very short pedicels (Fig. 163 *A*); *e.g.*, the inflorescence of the Plantain (Plantago).

The small spikes of the Glumales are termed *spikelets* (Fig. 171).

(2) The *spadix*, which differs from the spike only in having a thick and fleshy axis; a large bract forming a sheath, called a *spathe*, commonly grows at the base of the inflorescence and envelopes it more or less; *e.g.*, Arum and Richardia.

(3) The *raceme*, in which the flowers have long pedicels of nearly equal length; *e.g.*, the Cruciferæ, as the Radish, Cabbage, etc.; in these the bracts of the individual flowers are not developed; also Berberis and others, but not the Grape-vine (below No. 7).

(β) With a short axis; the flowers are set closely together on the short or flattened main axis.

(4) The *capitulum* (head) in which the short main axis is conical

or disc-shaped or even hollowed out, and is closely covered with sessile flowers (Fig. 163 *D*); *e.g.*, the Compositæ, as Dandelion, Sunflower; also the Scabious. The bracteoles (paleæ) of the individual flowers (Fig. 163 *Dp*) are sometimes wanting; but the whole head is surrounded at the base by a number of bracts forming an *involucre* (Fig. 163 *D c*) which gives the inflorescence the appearance of being one flower.

(5) The *umbel*, composed of a large number of flowers with long pedicels which spring together from a very short axis which commonly terminates in a flower (Fig. 163 *C d*); *e.g.*, the Umbelliferæ and the Ivy. The bracts of the separate pedicels forming *the rays* are usually present in diminished number; they form an involucre.

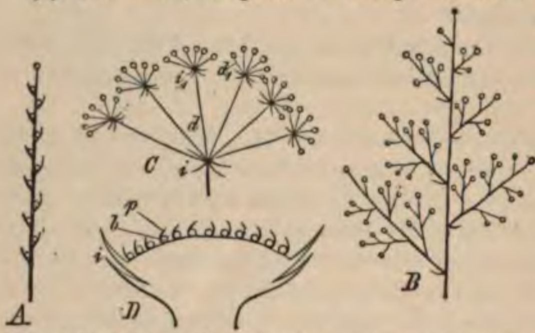


FIG. 163.—Diagrams of the varieties of racemose inflorescences. *A* Spike. *B* Compound raceme. *C* Compound umbel; *d* rays of the umbel; *i* involucre; d_1 secondary rays of the umbellulæ; i_1 involucel. *D* A capitulum; *i* involucre; *b* flower; *p* paleæ.

II. *Compound racemose inflorescences* are formed when the lateral shoots which bear the flowers as described above are again branched, or, in other words, when inflorescences of the types above enumerated are united to form a larger inflorescence; for instance, when several capitula are arranged on the main axis in the same way as the flowers of a raceme. The same terms are applied to the first ramification of the compound inflorescence as to the simple ones described above; the above-mentioned example, for instance, is a raceme of capitula, and is termed a capitulate raceme. Compound inflorescences may be classified as follows:

(a) *Homogeneously compound;* in these the branches of the first and second (or higher) orders are of the same character.

(6) The *compound spike;* in this form many simple spikes are arranged on the main axis of the inflorescence in the same way as the flowers in a simple spike, or, in other words, the main axis of the spike gives rise to secondary spikes instead of to single flowers; *e.g.*, the inflorescence of Wheat, Rye, etc.

(7) The *compound raceme;* in this case smaller racemes grow on

the main axis of the raceme; the ramification is in many cases still further repeated in such a way that it is more complex at the base of the primary raceme than towards the apex; *e.g.*, the Grape-Vine (Fig. 163 *B*).

(8) The *compound umbel* (Fig. 163 *C*). This is far more common than a simple umbel, and is in fact usually called an umbel; the separate simple umbels (Fig. 163 *C d*) are then called *umbellules* and their respective involucres are *involucels*.

(*β*) *Heterogeneously compound inflorescences;* in these the branches of the different orders are dissimilar. In consequence of this so many complicated forms arise that it is impossible to enumerate and name all the combinations. As examples, the following will only be mentioned: the *capitulate raceme*, which consists of a number of capitula arranged in a raceme; it occurs in many of the Compositæ *e.g.*, Petasites: the *spicate capitulum*, which consists of several spikes forming a capitulum, as in the Scirpeæ: the *spicate raceme* which occurs in many Grasses, in which the last branches of a compound raceme are spikes.

B. *Cymose inflorescences.* The main axis, which terminates in a flower, produces below its apex one or a few lateral branches—rarely several—which also terminate in flowers, but grow more vigorously than the main axis and repeat the same type of ramification.

I. In the *simple cyme* the ramification in the secondary and higher orders follows the same type.

(*a*) *Without a pseud-axis* (see page 20).

(9) The *cyme:* beneath the terminal flower spring several—three or more—lateral shoots of equal vigour, *e.g.*, many Euphorbiæ This inflorescence greatly resembles the true umbel, and in fact cannot be distinguished from a true umbel which has a terminal flower. The identification of an inflorescence as belonging to the cymose type depends in many cases on the fact that in the higher orders of branching the cymes are reduced to dichasia.

(10) The *dichasium* (Figs. 18 and 19 *C*) consists of only two equal lateral shoots arising at the same level below the terminal flower, and branching in a similar manner. The successive false dichotomies commonly decussate; *e.g.*, Valerianella and the weaker inflorescences of many Euphorbiæ.

(*β*) *With a pseud-axis.*

(11) The *helicoid cyme* (bostryx): the lateral branches of the successive ramifications always occur on the same side (Fig. 19 *D*):

this is frequently found in Monocotyledons, such as Hemerocallis, Ornithogalum, Alstrœmeria.

(12) The *scorpioid cyme* (cicinnus): in this the lateral branches occur alternately on opposite sides (Fig. 19 *A* and *B*).

Recent researches have shown, however, that in many cases (various Solanaceæ and Boragineæ) the so-called scorpioid cymes are monopodial; the axis is therefore not a pseud-axis but a true one, and the inflorescence must be regarded as a unilateral raceme.

II. *Compound cymose inflorescences* arise on one hand from the reduction of the ramification in the higher orders, as, for instance, when the secondary members of a cyme are not cymes but dichasia: these are *dichasial cymes;* they occur in many Euphorbiæ: again. when dichasia terminate in scorpioid or helicoid cymes. On the other hand it sometimes occurs that helicoid cymes are combined to form scorpioid cymes, as in Geranium.

C. *Compound racemose and cymose inflorescences.* It may occur that a compound inflorescence changes in type in the different orders of ramification. Thus the branches of the first order may exhibit a racemose arrangement, and those of the second a cymose arrangement, as in the dichasial racemes of many Euphorbiæ (*e.g.*, *E. Esula*, *amygdaloides*), in the scorpioid racemes of the Horse-chestnut, and in the helicoid capitula of many species of Allium. On the other hand the branches of the first order may have a cymose, and those of the second a racemose arrangement; for instance, the helicoid cymes of capitula in Cichorium.

Finally, there are certain terms used in describing inflorescences which refer only to the general external appearance rather than to the mode of formation of the inflorescence: thus, the *panicle* is a pyramidal inflorescence generally of the racemose type, at least in its first ramification: the *corymb* is a compound racemose inflorescence of which all the ultimate ramifications lie in one plane and bear flowers, *e.g.*, many Cruciferæ: the *amentum* (catkin) is a simple or compound inflorescence, usually pendulous and elongated, bearing inconspicuous flowers, which falls off entire from the plant when the flowering is over. Of cymose inflorescences there is the *fascicle*, consisting of a number of flowers on pedicels of equal length (Sweet William); the *glomerule* (Nettle and Box) or *verticillaster* (many Labiatæ), consisting of a few sessile or shortly pedicillate flowers; and the *anthela*, which is a compound inflorescence, in which the branches of the first order are gradually shorter from below upwards (or rather from without inwards), as in Juncaceæ.

CLASS IX.—MONOCOTYLEDONS.

The embryo has but one cotyledon; the endosperm is usually abundant in the ripe seed.

The embryo is usually small in comparison with the mass of endosperm (Fig. 164 *I e c*). The axis of the embryo terminates at the posterior end in a very short radicle and bears anteriorly a sheathing cotyledon which is considerably larger than the whole of the rest of the embryo, and which not unfrequently encloses one or more of the first minute alternating leaves.

On germination, the upper end of the cotyledon commonly remains in the seed and absorbs the nutritious substances deposited in the endosperm (Fig. 164 *II.–IV.*); the lower part of the cotyledon elongates and pushes the rest of the embryo out of the seed. In Grasses the cotyledon has a peculiar shield-like form, and is termed the

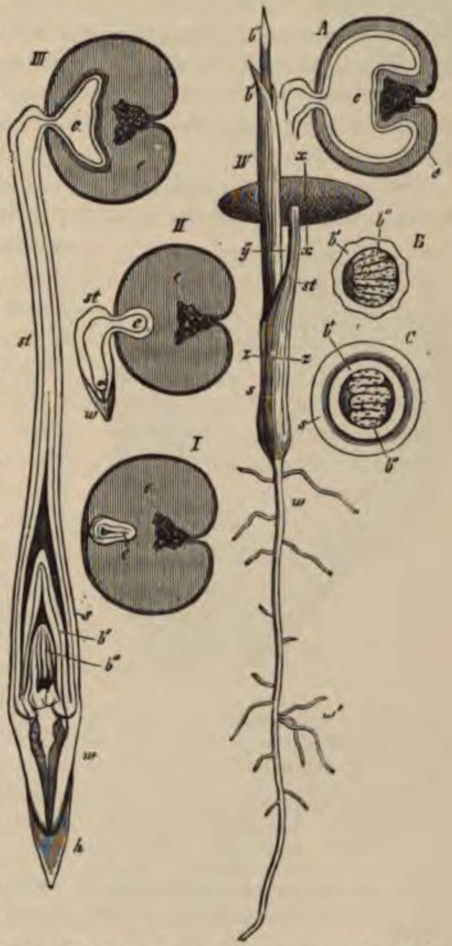


FIG. 164.—Germination of *Phœnix dactylifera*, the Date. *I.* Transverse section of the dormant seed. *III.*, *IV.* Different stages of germination (*IV.* the natural size). *A* Transverse section of the seed at *x x* in *IV*. *B* Transverse section of the seedling at *x y*: *C* at *z z*. *e* The horny endosperm; *s* the sheath of the cotyledon; *st* its stalk; *c* its apex developed into an organ of absorption which gradually consumes the endosperm and at length occupies its place; *w* the primary root; *w'* secondary roots; *b' b''* the leaves which succeed the cotyledon (*b''*) becomes the first foliage-leaf; in *B* and *C* its folded lamina is seen cut across. (After Sachs.)
]

scutellum (Fig. 165 *sc*): in the ripe seed it almost entirely encloses the embryo, and is in contact by its outer surface with the endosperm; during germination the cotyledon absorbs the nutritious matters contained in the endosperm, while the stem with the other leaves grows out of the seed. In other Monocotyledons the cotyledon is either a sheathing scale, or it is the first green leaf, differing but little from the foliage-leaves which are subsequently developed.

The primary root usually remains small and inconspicuous; adventitious roots are developed in succession at higher and higher levels upon the stem.

The stem of Monocotyledons is traversed longitudinally by scattered closed fibro-vascular bundles; it has therefore no growth in thickness by the means of cambium. In a few genera only, as Yucca and Dracæna, it grows subsequently in thickness by the formation of meristem in the external layers of the ground-tissue from which additional closed fibro-vascular bundles are developed.

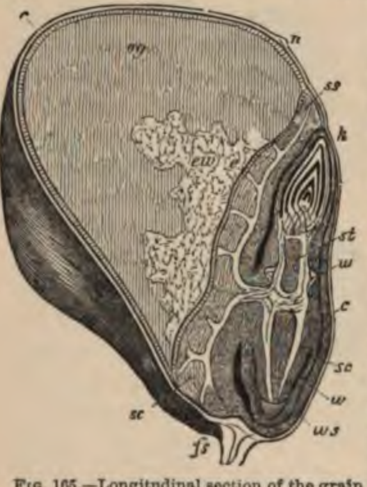


FIG. 165.—Longitudinal section of the grain of *Zea Mais* (× about 6): *c* pericarp; *n* remains of the stigma; *fs* base of the grain; *eg* hard yellowish part of the endosperm; *ew* whiter less dense part of the endosperm; *sc* scutellum of the embryo; *ss* its apex; *e* its epidermis; *k* plumule; *w* (below) the primary root; *ws* its root-sheath; *w* (above) secondary roots springing from the first internode of the embryonic stem (*st*). (After Sachs.)

The axis of the embryo in many cases continues to be the main axis of the plant; at first it is thin and weak, and since no subsequent growth in thickness of the stem takes place, and since the successive portions of the stem are thicker and more vigorous, the whole stem gradually assumes the appearance of an inverted cone, but when the plant has reached a certain height it may then grow cylindrically; this is the reason why in Palms, in the Maize, and other similar erect stems, there is a diminution in thickness at the lower end. Frequently, however, the primary axis of the plant perishes when it has given rise to lateral shoots.

The arrangement of the leaves is at first alternate: when the stem is well developed this alternate arrangement often passes over into complex spiral arrangements, as in Fritillaria and in Palms, in which plants a crown of leaves is conspicuous. In the Grasses and a few other families, the phyllotaxis is permanently alternate. A whorled arrangement of the foliage-leaves occurs but rarely.

The leaves commonly have a distinctly developed sheath but no stipules. The lamina is usually entire, simple in outline, often long and narrow, linear or ensiform, more rarely orbicular, cordate or sagittate. Branched leaves occur only in a few of the Aroideæ. The pinnate or palmate leaves of the Palms acquire this form by the splitting of the originally entire lamina, and the same is the case with the perforated leaves of many Aroideæ.

The venation of the leaves is characterized by the fact that the weaker veins do not usually project on the under surface. In linear leaves, and in such as are inserted by a broad base, the stronger veins run almost parallel; in broader ones, *e.g.*, Lily of the Valley (*Convallaria majalis*), they describe a curve which is more or less parallel to the margin; the weaker veins usually run at right angles between the stronger ones. In the Scitamineæ and a few other plants, a number of parallel transverse veins are given off at various angles (sometimes very acute, and sometimes nearly right angles) from the median vein. Reticulate venation of the leaves is very unusual; it occurs in Aroids and in *Paris quadrifolia.*

The flower of Monocotyledons consists typically of five alternating and isomerous whorls, two belonging to the perianth, two to the andrœcium and one to the gynœcium. Thus the typical formula is Kn, Cn, An + n, Gn, where n in most cases = 3, more rarely = 2, 4 or 5. The members of the perianth usually resemble each other in texture.

This type is most closely adhered to in the Liliaceæ. The first departure from it is exhibited in the abortion of the inner whorl of stamens in the Irideæ, and in the inferior position of the ovary. This latter character occurs also in the Scitamineæ and Orchidaceæ, which are also characterized by the zygomorphism of their flowers and the considerable reduction of the andrœcium.

Other various and considerable reductions of the parts of the flower occur among the Aroideæ, and constant reduction in the Glumales and Typhaceæ.

In the case of certain water-plants, development appears to have been arrested at an early stage. In others, the number of the members of the gynœcium and to some extent even of the andrœcium is not constant, and the spiral arrangement predominates (Alismaceæ).

The simply organized water-plants may be regarded in some cases as reduced forms, as the Lemnaceæ, while some seem to be representatives of a special type, as the Naiadeæ.

The Monocotyledons may be classified as follows:

Sub-class I. NUDIFLORÆ.
Series i. SPADICIFLORÆ.
Cohort 1. **Potamales.**
Order 1. NAIADEÆ.
Cohort 2. **Arales.**
Order 1. AROIDEÆ.
" 2. LEMNACEÆ.
" 3. PANDANEÆ.
" 4. CYCLANTHEÆ.
" 5. TYPHACEÆ.
Cohort 3. **Palmales.**
Order 1. PALMÆ.
Series ii. GLUMIFLORÆ.
Cohort 1. **Glumales.**
Order 1. GRAMINEÆ.
" 2. CYPERACEÆ.
Cohort 2. **Restiales.**
Order 1. ERIOCAULONEÆ.
" 2. RESTIACEÆ.

Sub-class II. PETALOIDEÆ.
Series i. HYPOGYNÆ.
Sub-series. *Apocarpæ.*
Cohort 1. **Alismales.**
Order 1. JUNCAGINEÆ.
" 2. ALISMACEÆ.
" 3. BUTOMACEÆ.
Sub-series. *Syncarpæ.*
Cohort 1. **Commelynales.**
Order 1. XYRIDEÆ.
" 2. COMMELYNACEÆ.
Cohort 2. **Liliales.**
Order 1. LILIACEÆ.
" 2. JUNCACEÆ.
" 3. PONTEDERIACEÆ.
Series ii. EPIGYNÆ.
Cohort 1. **Hydrales.**
Order 1. HYDROCHARIDACEÆ.
Cohort 2. **Dioscorales.**
Order 1. DIOSCOREÆ.
" 2. TACCACEÆ.
" 3. BROMELIACEÆ.
Cohort 3. **Amomales (Scitamineæ).**
Order 1. MUSACEÆ.
" 2. ZINGIBERACEÆ.
" 3. MARANTACEÆ (CANNACEÆ).
Cohort 4. **Orchidales.**
Order 1. ORCHIDEÆ.
Cohort 5. **Narcissales.**
Order 1. IRIDEÆ.
" 2. AMARYLLIDEÆ.

SUB-CLASS I. NUDIFLORÆ.

Flowers unisexual or hermaphrodite: perianth wanting, or consisting of scales: ovary superior.

SERIES I. SPADICIFLORÆ.

Flowers usually in a spike or spadix with a spathe, sometimes solitary: anthers usually extrorse, or dehiscing by pores.

Cohort 1. **Potamales**: Order 1. NAIADEÆ. Perianth 0, or of 2–4 segments: stamens 1–4: gynœcium apocarpous, ovaries 1–4, with usually a single erect or suspended ovule: seed without endosperm. Water-plants.

In the genus Naias the flowers are solitary or in spikes, and are diœcious: perianth 0: male flowers with 1 stamen, female flowers with 1 carpel: ovule erect. *N. flexilis* is the only British species.

The flowers of Phucagrostis generally resemble those of Naias, but the male flower has 2 stamens, and the female 2 carpels. This genus is found in the Mediterranean.

In Zostera, the Grass-wrack, the flowers are unisexual, monœcious, and without a perianth; they are borne in two rows on one side of a spadix; stamen 1, carpel 1. *Zostera marina* and *nana* are the British species.

Zostera and Phucagrostis live in the brackish water of estuaries; they are remarkable in that their pollen-grains are filiform.

In Zanichellia, the Horned Pondweed, the flowers are monœcious, and are solitary or in spikes; male flower, perianth 0, stamen 1; female flower, perianth bell-shaped, carpels 4–6. *Z. palustris* is the only British species.

In Ruppia, the Tassel Pondweed, the flowers are hermaphrodite, and there are generally two on a spike; formula $P0, A2, G4$. *R. maritima* is the British species.

In Potamogeton, the Pondweed, the flowers, which are hermaphrodite, are in spikes; general formula $P4, A2+2, G\times 4$; the stamens are inserted on the segments of the perianth. This genus is represented in Britain by many species: in some (*P. pusillus*) the stem bears only submerged leaves which are narrow and linear; in others the leaves are somewhat broader (*P. densus*), and in others again it bears a few broad leaves which float on the water (*P. natans*).

Cohort 2. **Arales.** The flowers are small and numerous, the inflorescence a spadix or a panicle with thick branches, commonly enclosed in a greatly developed spathe; the bracteoles of the individual flowers are frequently wanting; perianth 0, or polyphyllous; the flowers are usually diclinous, but both sexes frequently occur in the same inflorescence: gynœcium apocarpous or syncarpous: the seeds have a large endosperm: the embryo is straight and minute.

Order 1. AROIDEÆ. Flowers monœcious or hermaphrodite: perianth 0 or of 4 segments: stamens many or definite: ovary uni- or multilocular: fruit a berry.

In many of the genera the flowers are complete and conform to the monocotyledonous type, *K*n, *C*n, *A*n + n, *G* $(\underline{\text{n}})$, where n may stand for 3, 2 or 5, as in Acorus (Fig. 166), in which the flowers are exactly typical. In other genera, however, the flowers are reduced in various ways and degrees; not only does the perianth disappear, but the number of the stamens and carpels is frequently diminished. An extreme case is offered by those diclinous flowers of which the male consists of only a single stamen, and the female of only one monomerous ovary. These much reduced flowers are disposed in regular order on the spadix; thus in Arum (Fig. 167) the numerous female flowers, consisting each of one carpel (Fig. 167 *f*), are inserted on the base of the spadix, and the male flowers, each consisting merely of a few stamens, are closely packed higher up on it (Fig. 167 *a*). The upper part of the spadix is covered with rudimentary flowers (*b*, *c*). When, as in this case, the perianth of the true flowers is wholly wanting, the whole inflorescence may assume the aspect of a single flower; but irrespectively of the numerous intermediate forms which are to be found, such a view is untenable when it is borne in mind that here the ovaries are invariably situated below the stamens, while in a flower they are invariably above them.

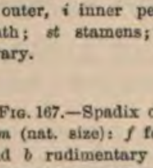


FIG. 166.—Flower of *Acorus Calamus* (mag.): *a* outer, *i* inner perianth; *st* stamens; *f* ovary.

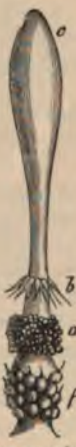


FIG. 167.—Spadix of *Arum maculatum* (nat. size): *f* female; *a* male; and *b* rudimentary flowers; *c* the upper club-shaped end of the spadix.

The stem may be underground, a tuber, or a rhizome, or it may be aërial; in the latter case it often climbs, clinging to trees by means of aërial roots. The leaves are either alternate and distichous or, more often, spiral with a divergence of $\frac{2}{5}$. They are rarely narrow, linear, or ensiform, and commonly consist of sheath, petiole, and blade; the venation is reticulated, and the leaf often exhibits a more or less complicated segmentation.

Sub-order 1. ORONTEÆ. Flowers usually hermaphrodite and with a perianth. *Acorus Calamus*, the Sweet Flag, originally a native of Asia, is found occasionally in ponds and ditches in Britain. The underground rhizome bears long ensiform leaves and a triangular scape bearing a terminal spadix which, however, is pushed on one side by the spathe which is long and narrow, and appears as a prolongation of the stalk. The spadix is closely covered with perfect flowers (Fig. 166).

Sub-order 2. AREÆ. Flowers diclinous and without a perianth.

Arum maculatum, the Cuckoo-pint or Lords-and-Ladies, is common in woods and hedge-rows; the large green spathe completely envelopes the spadix (Fig. 167). *Richardia ethiopica* is a cultivated plant well known under the name of Calla or Colocasia; it has a large white funnel-shaped spathe. The species of Philodendron have climbing stems and large leaves which are frequently perforated.

Pistia Stratiotes, a tropical water-plant, is characterized by having the flowers on the spadix reduced to two, one male flower, and one female flower consisting of a single carpel; the spadix and spathe are adherent. It appears highly probable that the Lemnaceæ, mentioned below, are in fact very simple forms of this family.

Order 2. LEMNACEÆ. Stem leafless. Each inflorescence consists of two male flowers and one female flower borne on a lateral prominence of the stem: the male flowers consist of a single stamen, and the female flower of one carpel.

Lemna trisulca, *polyrhiza*, *minor* and *gibba*, are known as Duck-weed; they are common in tanks and ponds, floating on the water. The stem, which is leafless, is almost flat, resembling a thallus: it bears two rows of branches (Fig. 168), as also roots on its under surface which are suspended in the water. Roots are, however, absent in *Wolffia arrhiza*, which is also devoid of fibro-vascular bundles: its flower has no spathe, and it bears only one row of branches: it is the smallest known flowering plant.

Order 3. PANDANEÆ. Flowers diœcious, perianth 0; the female flowers each consist of a single carpel; they are closely crowded on the spadix, which becomes a spurious fruit: the male flowers have numerous stamens.

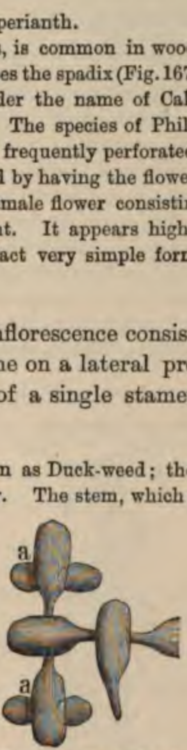


FIG. 168.—Part of a plant of *Lemna trisulca*, seen from above: *a* the young lateral branches (nat. size).

Pandanus utilis, the Screw-Pine, and other species, form thickets in the tropics, particularly on the banks of rivers. The straight woody stems, which subsequently branch, give off numerous strong roots which attach them to the soil, and bear crowns of large narrow linear leaves, the margins of which are frequently set with sharp spinous teeth. The tough fibro-vascular bundles are used for the manufacture of fabrics.

Order 4. CYCLANTHEÆ. Plants of a palm-like habit in Southern and Central America; the flowers, which usually have a perianth, are disposed on the spadix in regular spirals: they are monœcious.

The leaves of *Carludovica palmata* are applied to various purposes, *e.g.*, Panama hats are woven of them.

Order 5. TYPHACEÆ. Flowers monœcious, the perianth represented only by scales or hairs. Stamens 1–6. Ovary monomerous containing one ovule. Inflorescence a spadix, without a spathe, elongated or compact.

In Sparganium, the Bur-reed, the inflorescences are spherical spikes which are borne terminally and laterally in two rows on the upper part of the stem. The lower spikes bear only female and the upper only male flowers; the perianth consists of scales; stamens 2–3, free. *Sparganium simplex* and *ramosum* are not rare in ditches.

Typha, the Reed-mace or Bulrush, bears its flowers on a long terminal spadix; the male flowers are borne at the upper and thinner portion directly on the main axis; on the lower and thicker portion are borne the female flowers, which grow partly on the main axis and partly on very short lateral shoots; the perianth is replaced by long hairs; stamens 3, monadelphous. *Typha angustifolia* and *latifolia* occur in bogs and wet places.

Cohort 3. **Palmales.** Order 1. PALMÆ. The flowers are diœcious or monœcious, rarely hermaphrodite or polygamous, and they generally conform to the type $K3$, $C3$, $A3+3$, $G^{\underline{(3)}}$: in rare instances a larger or a smaller number of stamens are present: anthers sometimes introrse: carpels, in rare cases, only two or one: ovary monomerous, or polymerous with from one to three loculi. The flowers are inserted with or without bracteoles on a spadix or on the thick axis of a spicate or paniculate inflorescence (Fig. 169).

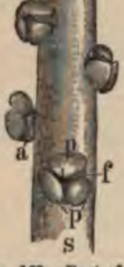


FIG. 169.—Part of the female panicle of Chamædorea: *s* the thick axis; *a* the external; and *p* the internal whorl of the perianth; *f* ovary (× 3).

Their mode of growth is somewhat various. Most Palms bear their leaves closely arranged in a crown at the top of a tall or of a quite short stem, which is clothed for some distance below its apex with the remains of the older withered leaves. But in some genera, *e.g.*, Calamus, the stems creep or climb and the leaves are inserted at some distance from each other. The blade of the leaf commonly splits in the course of its growth, assuming a palmate or pinnate form.

Palms chiefly inhabit the tropics, particularly the Moluccas, Brazil, and the region of the Orinoco.

Phœnix dactylifera (the Date Palm), a native of Asia and Africa, has pinnatifid leaves. Of the three ovaries, one only developes to form the fruit which is known as the date; the stone of the date consists of a very thin testa enclosing the large mass of endosperm in which the embryo is imbedded. *Cocos nucifera* (the Cocoa-nut Palm) has, as is well known, many uses. The fruit itself is a gigantic drupaceous fruit; the mesocarp is traversed by an immense number of fibro-vascular bundles, which are used to make ropes, etc. Inside the excessively hard wall of the fruit itself, the endocarp, lies a single large seed. When the fruit is mature, the endosperm forms a layer only a few millimetres in thickness, which lines the hard shell; the rest of the space is filled with fluid, known as cocoa-nut milk. The embryo, which is small, is imbedded in the firm tissue of the endosperm, under the spot where there is a hole in the endocarp. *Sagus Rumphii*, belonging to the Moluccas, yields Sago, which is in fact the starchy parenchyma of the stem. *Elais guineensis* is the Oil-Palm of West Africa; the mesocarp of the plum-like fruit yields the oil. The stems of various species of Calamus constitute the so-called Spanish cane. The large and very hard endosperm, with much-thickened cell-membranes, of *Phytelephas macrocarpa*, is used in turnery, and is known as vegetable ivory. *Chamærops humilis*, the Fan-Palm, is found in Southern Europe and Northern Africa. *Livistona australis* is frequently cultivated for the sake of its graceful, fan-like, palmatifid leaves.

SERIES II. GLUMIFLORÆ.

Flowers hermaphrodite or unisexual, usually in heads or spikelets invested by imbricate bracts or glumes: ovary uni- or multilocular, with one ovule in the loculus: seeds with endosperm.

Cohort 1. **Glumales.** Ovary unilocular: ovule erect.

Order 1. GRAMINEÆ. True Grasses. The leaves are alternate on the stem, which is known as the haulm; the embryo lies on the side of the endosperm (Fig. 165). The usually hermaphrodite flowers are referable to the formula $K0, C2, A3 + 0, G^{\underline{(2)}}$; they are enclosed by bracts here termed *paleæ*, and are arranged in complicated inflorescences; the perianth-leaves assume the form of small scales termed *lodicules*; the unilocular ovary contains only one ovule; the grain is the fruit, a caryopsis, to which the two paleæ sometimes adhere, *e.g.*, Barley and Oats.

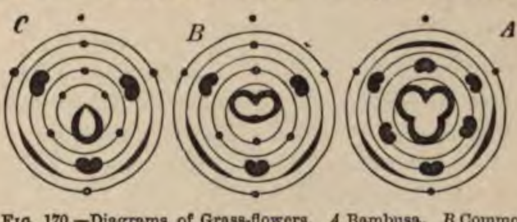


FIG. 170.—Diagrams of Grass-flowers. *A* Bambusa. *B* Common type of Gramineæ. *C* Nardus.

A flower of this composition is sessile in the axil of a bract, which is termed the *inferior* or *outer palea* (Fig. 171 b_1, b_2...), and there is also a bracteole beneath the perianth which is termed the *superior* or *inner palea.* The two paleæ completely enclose the flower. Usually two or more flowers which are thus enclosed by the paleæ are present on an axis (Fig. 171 *x*), and constitute the spikelet of the Grass, and beneath the lowest flower there are usually two more bracts which bear small sterile flowers in their axils and which are known as the *glumes* (Fig. 171 *g*). Thus a spikelet consists of an axis bearing two rows of bracts of which the two first and lowest are barren, while the succeeding ones bear each a flower in its axil, and beneath each flower there is also a bracteole or palea belonging to the floral axis itself. The inferior paleæ often have, either at the apex or else borne on the midrib, a spinous process called the *arista* or *awn* (Fig. 171 *gr*).

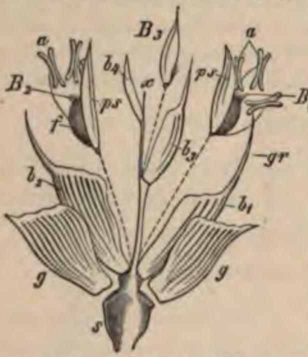


FIG. 171.—A spikelet of Wheat dissected (mag.): *x* axis of the spikelet; *g* glumes; b_1 b_2 the inferior paleæ bearing (*gr*) the awn. B_1 B_2 the flowers raised from the axis out of the axils of the superior paleæ, *ps*; *a* anthers; *f* ovaries.

The number of flowers in each spikelet varies according to the genus; often there is but one, the lowest, with rudiments of others above it; if, however, only one of the upper flowers is developed, so that the lower paleæ bear no flowers in their axils, they are regarded as glumes, several being therefore present in such a case. The spikelets themselves are in many genera, *e.g.*, Rye and Wheat (Fig. 172 *B*), arranged in two rows on a main axis; the inflorescence may then be designated a spike; in most of the other genera the main axis of the inflorescence bears lateral branches which are slender, of various length, and often branched again, and which bear the terminal spikelets; in this way a panicle is formed, as in the Oat (Fig. 172 *A*). This may be either loose and spreading, with long lateral branches (Fig. 172 *A*), or compressed, with very short branches, *e.g.*, Alopecurus.

The stem is usually tall and the long internodes are hollow; the sheath of the leaf is largely developed and frequently extends over several internodes. A membranous ligula is often found at the junction of sheath and lamina (Fig. 8 *A*).

The Grasses are classified as follows:

Sub-order 1. CLISANTHEÆ. Spikelets closed in flower: styles or stigmas long, protruding beyond the apex of the inferior palea.

Tribe 1. *Paniceæ.* Spikelets dorsally compressed, 1-flowered: glumes 3, of which the lowest is the smallest.

Panicum glabrum (*Digitaria humifusa*), *P.* (*Echinochloa*) *Crus-galli*, and *P.* (*Setaria*) *viridis* occur occasionally on cultivated land.

Tribe 2. *Phalarideæ.* Spikelets laterally compressed, 1-flowered: glumes 4, the inner pair being smaller. *Phalaris arundinacea*, the Reed-grass, is common on the banks of streams, etc.: a variety with white-streaked leaves is cultivated in gardens. *Anthoxanthum odoratum*, Vernal Grass, which has only two stamens and a paniculate inflorescence, is common in meadows: it gives the peculiar odour to fresh hay.

Tribe 3. *Andropogoneæ.* Flowers monœcious or polygamous: glumes 3, of which the lowest is the largest. *Zea Mais*, the Maize Plant, is cultivated in warm countries: its flowers are monœcious: the male flowers form a loose panicle at the apex of the haulm, and the female flowers are borne laterally on a thick spadix, which is ensheathed by leaves. *Saccharum officinarum*, the Sugar-cane, is a native of the East Indies.

Tribe 4. *Chlorideæ.* Spikelets laterally compressed, usually 1-flowered, in compound spikes: glumes 2. *Cynodon Dactylon*, the Dog's-tooth-grass, is often abundant on waste ground. *Spartina stricta* occurs in salt marshes.

Tribe 5. *Phleineæ.* Spikelets laterally compressed, 1-flowered, in dense panicles: glumes 2.

Alopecurus, the Fox-tail-grass, has the glumes coherent at the base, and one rudimentary palea. Phleum, the Cat's-tail-grass, has free glumes and two distinct paleæ.

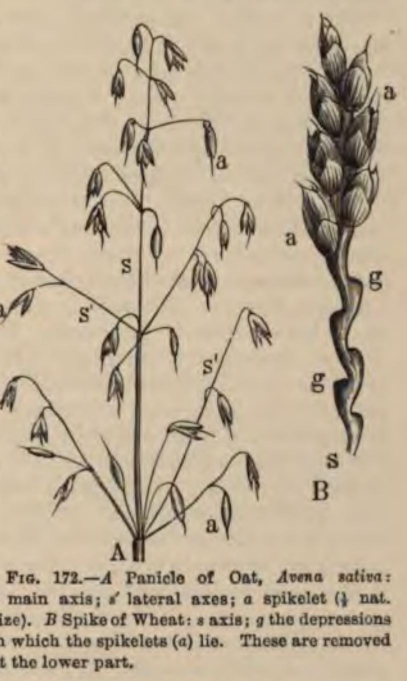


FIG. 172.—*A* Panicle of Oat, *Avena sativa*: *s* main axis; *s'* lateral axes; *a* spikelet (½ nat. size). *B* Spike of Wheat: *s* axis; *g* the depressions in which the spikelets (*a*) lie. These are removed at the lower part.

Tribe 6. *Sesleriеæ.* Spikelets laterally compressed, 2-flowered or more, in dense panicles: glumes 2. *Sesleria cærulea*, the Moor-grass, occurs on mountains.

Tribe 7. *Nardeæ.* Spikelets 1-flowered, in simple spikes: glumes 0.

Nardus stricta, the common Mat-grass, occurs on moors and heaths.

Sub-order 2. EURYANTHEÆ. Spikelets open in flower: styles short, stigmas protruding near the base of the inferior palea.

Tribe 1. *Oryzeæ.* Spikes laterally compressed, usually 1-flowered: glumes 4, often represented only by bristles. *Oryza sativa* is the Rice-plant—from the

East Indies; cultivated in marshy regions of Southern Europe. *Leersia oryzoides*, the Cut-grass, is found in ditches in the south of England.

Tribe 2. *Stipeæ*. Spikelets 1-flowered, cylindrical or flattened posteriorly: in panicles: glumes 2. *Stipa pennata*, the Feather-grass, has a long airy awn. *Milium effusum*, without an awn, is common in woods.

Tribe 3. *Agrostideæ*. Spikelets 1-flowered, compressed laterally, in loose panicles: glumes 2.

In Agrostis, the Bent-grass, the axis of the spikelet is glabrous, or it bears short hairs; *A. vulgaris* and *stolonifera* are common in meadows and woods: *Apera Spica venti* is common in fields: in Calamagrostis, the Small reed, several species of which occur on the banks of rivers and woods, the axis of the spikelet is covered with long hairs.

Tribe 4. *Aveneæ*. The spikelets consist of several (usually two) flowers; the glumes (or one of them at least) are as long as the whole spikelet.

Avena, the Oat, has loose panicles, and a two-toothed inferior palea: of this genus there are many species; *A. fatua*, *pratensis* and *pubescens*, are common in cornfields and meadows. The following species are cultivated: *A. sativa*, with its panicles in various planes; *A. orientalis*, with its panicles in one plane; *A. strigosa*, with a hairy floral axis; and *A. nuda*, the spikelets of which usually consist of three flowers. *Aira cæspitosa* and *flexuosa* have truncate inferior paleæ, and are common in meadows and woods. Holcus, the Honey-grass, has spikelets consisting of two flowers, the upper of which is usually male, and the leaf-sheaths are covered with silky hairs; it is common in damp meadows.

Tribe 5. *Festuceæ*. The spikelets are usually many-flowered, and the glumes shorter than the lowest inferior palea. Melica, the Melic-grass, has sometimes spikelets consisting of a single flower only; the glumes are long; it is common in woods. Briza, the Quaking-grass, has spikelets which are compressed laterally and are cordate at the base; it is common in meadows. *Koeleria cristata* has dense panicles; it is common in dry meadows. *Dactylis glomerata*, the Cock's-foot-grass, has dense panicles divided into parts which have longer stalks; it is common in meadows. *Poa pratensis*, *trivialis*, etc., are common in meadows; their spikelets are compressed laterally; the glumes have a sharp keel; *P. annua* is common by the roadside. *Festuca elatior*, and others, the Fescue Grasses, are common in meadows. Bromus, of which there are several species, is common in fields (*B. secalinus*), in meadows (*B. mollis* and others), by the roadside (*B. sterilis*, *tectorum*). *Molinia cærulea* has a very long haulm, consisting for the most part of a single internode; its spikelets are in loose purplish panicles; it occurs on moors. In Phragmites the axis of the spikelet is covered with long silky hairs: *Phragmites communis*, the Reed, occurs abundantly in marshes.

The upper flowers in the spikelets of plants belonging to this tribe are often unisexual, male; Phragmites is peculiar in that the lower flower of the spikelet is male.

Tribe 6. *Hordeeæ*. Spikelets solitary, or 2 or 3 together, 1- or many-flowered, situated in depressions on the main floral axis, forming the so-called spike: glumes 1-2. In Lolium, the Rye-grass (*L. perenne* is common everywhere), the posterior surface (that is, the middle line of the posterior glume) is directed towards the main axis, and this glume is usually rudimentary. In all the other genera the side of the spikelet is directed towards the main axis, and there are two glumes. *Secale cereale*, the Rye, has 2-flowered spikelets and narrow awl-shaped glumes. Triticum, the Wheat, has 3- or more flowered spikelets, with ovate glumes: *T. repens*, the Twitch, is common everywhere; its spreading rhizome makes it a troublesome weed. The following species are cultivated; *T. vulgare*, the common Wheat, with long glumes, which have no keel, and *T. turgidum*, English Wheat, with short keeled glumes; both these forms have a wiry floral axis, and the fruit easily falls out of the glumes: *T. Spelta*, the Spelt, which has an almost quadrangular spike, and *T. dicoccum*, with a compact spike, have a brittle floral axis, and the fruit is firmly enclosed by the glumes. In all the species the length of the awn varies very much. Brachypodium has shortly-stalked spikelets, and its two glumes differ much in length: it is thus distinguished from Triticum. Hordeum, the Barley, has 3 single-flowered spikelets inserted together in one depression on the floral axis. *H. murinum* is common on the roadside and on walls. The following species are cultivated: *H. vulgare* and *H. hexastichum*, with only fertile spikelets; in the latter species the spikelets are all equally distant, and are therefore arranged in six rows; in the former species the median spikelets are nearer together, and the lateral ones more distant, so that they are described as being in four rows: further, *H. distichum* is the two-rowed Barley, the lateral spikelets of which are male, so that the fruits are arranged in two rows. The fruit usually adheres to the palea

Order 2. CYPERACEÆ. The leaves are arranged in three rows on the stem; perianth 0, or of 3–6 or more bristles or scales; the embryo is enclosed in the endosperm.

Tribe 1. *Cypereæ*. Spikelets compressed: flowers hermaphrodite; perianth 0, or of bristles: glumes distichous.

Cyperus, the Galingale, has many-flowered spikelets with deciduous glumes: Schœnus, the Bog-rush, has few-flowered (1–4) spikelets with persistent glumes. *C. longus* and *fuscus*, and *S. nigricans*, occur in England. *Cyperus Papyrus* is an Egyptian species from which the Papyrus of the ancients was made.

Tribe 2. *Scirpeæ*. Spikelets cylindrical; flowers hermaphrodite; perianth 0, or of bristles: glumes imbricate on all sides.

The spikelets are often arranged so as to form spikes, panicles, umbels, or capitula; the flower has the formula $K3$, $C3$, $A3 + 0$ or 3, $G^{(3)}$.

Scirpus, the Club-rush, has a bristly perianth; in some species the spikelets are solitary, as in *Scirpus cæspitosus*, in others there are lateral spikelets in addition on short stalks, as in *S. lacustris* (the true Bulrush), or on long stalks, as in *S. sylvaticus*. *Eriophorum polystachion* and others (Cotton-grass) are common on moors; the hairs of the perianth, after flowering, grow to a considerable length.

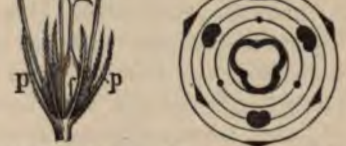


FIG. 173.—Flower of Scirpus (magnified): *p* the bristly perianth; *a* the three stamens; *f* the ovary. *B* Its floral diagram.

Tribe 3. *Cariceæ.* Spikelets cylindrical; flowers unisexual; perianth 0.

The Cariceæ have diclinous flowers with this peculiarity, that the male and female flowers differ in their structure. The male flowers have the formula $K0$, $C0$, $A3 + 0$, $G0$; they are situated in the axils of bracts (glumes) (Fig. 174 *B* and *D*) and form simple spikes. The female flowers have the formula $K0$, $C0$, $A0 + 0$, $G\underline{(3)}$ or $\underline{(2)}$ and are not sessile in the axils of the bracts (glumes) (*b* in Fig. 174 *A* and *C*), but a short branch springs from the axil of each of these leaves bearing a single bracteole (*s* in Fig. 174) and it is in the axil of this bracteole that the female flower, which consists of a trimerous or more rarely dimerous ovary, is situated. The bracteole (*s* in Fig. 174 *A* and *C*) increases greatly and invests the fruit, forming the so-called *utriculus:* this structure is often regarded as a perianth, and is termed the *perigynium*. In Elyna and Kobresia the bracteole is not tubular, and therefore does not completely invest the ovary.

The Genus Carex, the Sedge, contains numerous species which grow mostly in damp localities; they have stiff leaves with sharp or saw-like edges, but only a few of them are diœcious: in most the male and female inflorescences occur on the same axis. In one large section of them the two sexes occur on the same spike which is either male at the base and female at the top, or *vice versâ*. When this is the case the axis bears either only one terminal spike, as in *Carex pulicaris* and *C. pauciflora*, or several spikes forming a capitulum at the apex, as in *C. pseudo-cyperus*, or a spike or a panicle, as in *C. muricata* and *paniculata*. In the second section, on the other hand, each spike is unisexual, and then the male spike is almost always terminal on the axis and the female lateral, as in *Carex acuta*, *glauca*, *præcox*, *digitata*, *flava*, and *paludosa*.

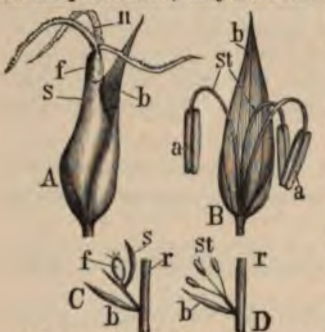


FIG. 174.—Flower of Carex (mag.). *A* Female flower with (*b*) bract (glume); *s* bracteole; *f* ovary; *n* stigma. *B* Male flower: *st* the three stamens; *a* anthers. *C* Diagram of the female and (*D*) of the male flower: *r* axis of the spike; *b* bract; *s* bracteole.

Cohort 2. **Restiales.** Ovary often multilocular; ovule orthotropous and suspended; hence in the seed the radicle of the embryo is directed away from the hilum (*enantioblastic*). Flowers unisexual, rarely hermaphrodite, with bracts: floral formula $K3$, $C3$, $A3 + 3$, $G(3)$, but occasionally some of the members are wanting.

Order 1. ERIOCAULONEÆ. Flowers unisexual, in capitula, often monœcious in the same capitulum, or rarely diœcious: stamens generally in two whorls, anthers generally bilocular: seed ribbed.

Eriocaulon septangulare, the Pipewort, occurs in the Hebrides and on the west coast of Ireland.

Order 2. Restiaceæ. Flowers usually unisexual, diœcious, and in spikes: not more than one whorl of stamens is present, anthers generally unilocular: seed smooth or tubercled.

These are grass-like plants all living in the southern hemisphere. This order includes the group Centrolepideæ (Desvauxiaceæ *Lindl.*); in these the perianth is much reduced, the male flower probably has only one stamen, and the female only one carpel.

SUB-CLASS II. PETALOIDEÆ.

Flowers hermaphrodite, rarely unisexual; perianth never wanting, usually biseriate, the members of at least one series usually petaloid.

SERIES I. HYPOGYNÆ.

Ovary superior.

Sub-series. Apocarpæ.

Gynœcium usually apocarpous.

Cohort 1. **Alismales.** Marsh or water plants; flowers sometimes unisexual; seeds without endosperm.

Order 1. Juncagineæ. Flowers sometimes diœcious; both perianth-whorls are sepaloid and inconspicuous; anthers extrorse; carpels sometimes coherent; the outer whorl of carpels is occasionally abortive; ovules 1–2, anatropous, embryo straight.

Triglochin palustre, the Arrow-grass, is common in marshes and on the margin of pools: carpels coherent till mature. The flowers are disposed spirally in a long loose spike without bracts. *Scheuchzeria palustris* is rarer; it occurs in bogs; the flowers are set in the axils of distichous bracts: carpels free.

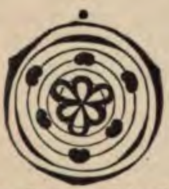


Fig. 175.—Diagram of the Flower of Triglochin.

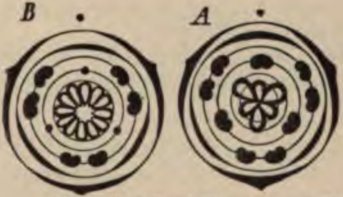


Fig. 176.—Floral diagrams. *A* Of Butomus. *B* Of Alisma.

Order 2. Alismaceæ. Flowers sometimes monœcious; floral formula $K3, C3, A3^2 + O$ or 3, or ∞, $G3 + 3$ or ∞; the outer perianth-whorl, which is sepaloid, is often coherent at the base; the inner whorl is petaloid, white or violet; anthers extrorse or introrse; carpels sometimes partially coherent; ovules 1–3, campylotropous, embryo curved.

Alisma Plantago (Water Plantain, Fig. 176 *B*), has the floral formula $K3$, $C3$, $A3^2$; the numerous, monomerous, one-seeded ovaries are crowded on the broad receptacle. The main axis of the inflorescence bears whorls of branches which have a helicoid ramification. It is rather common in damp spots.

Sagittaria sagittæfolia (the Arrowhead), with the floral formula $K3$, $C3$, ♂ $A\infty$, ♀ $G^{\underline{\infty}}$, is monœcious. The flowers are disposed in trimerous whorls, the male in the upper and the female in the lower whorls. The anthers are extrorse. The ovaries, which are very numerous and one-seeded, are inserted on a fleshy receptacle. Only the sagittate leaves and the inflorescence appear above the water.

Order 3. BUTOMACEÆ. Flowers never unisexual; general floral formula the same as in Alismaceæ; the inner whorl of the perianth is petaloid; anthers introrse; carpels distinct; ovules numerous, with superficial placentation; embryo curved.

Butomus umbellatus is the Flowering Rush (Figs. 176 *A*, 177). The flowers, which have violet petals, have the following formula: $K3$, $C3$, $A3^2+3$, $G^{\underline{3+3}}$; they are arranged in an umbellate helicoid cyme at the apex of the scape, which is about 3 feet high; this and the leaves, which are of about the same length, spring from an underground rhizome. The ovules, which are numerous, are borne on the inner surface of the carpels (Fig. 148 *C*).

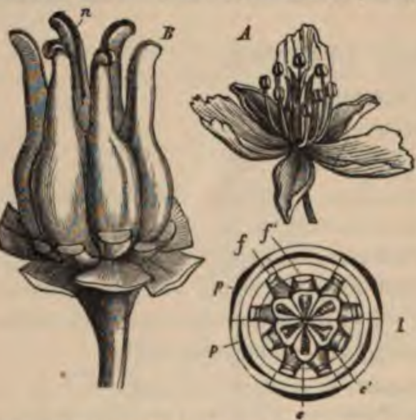


FIG. 177.—*Butomus umbellatus*. *A* Flower (nat. size). *B* Gynœcium (mag.); *n* stigmas. *I* Diagram: *p p* perianth; *f* stamens of the outer whorl reduplicate: *f'* stamens of the inner whorl; *c* outer, and *c'* inner whorl of carpels. (After Sachs.)

In the genus Limnocharis the stamens and carpels are indefinite.

Sub-series. *Syncarpæ.*

Gynœcium syncarpous.

Cohort 1. **Commelynales.** The inner whorl of the perianth is petaloid; seeds with endosperm.

Order 1. XYRIDEÆ. Herbaceous sedge-like plants; floral formula $K3$, $C3$, $A3+0$, $G^{\underline{(3)}}$; anthers extrorse; ovary usually unilocular, with parietal placentation.

These plants inhabit swamps in tropical or sub-tropical regions.

Order 2. COMMELYNACEÆ. Herbaceous plants; general floral formula $K3$, $C3$, $A3+3$, $G^{\underline{(3)}}$, but the number of stamens varies in the genera; anthers usually introrse; ovary usually trilocular.

These are mostly tropical plants. Species of Commelyna and Tradescantia are cultivated as ornamental plants.

Cohort 2. **Liliales.** The calyx and corolla resemble each other in texture, and are usually petaloid; seeds with endosperm; general floral formula $K3$, $C3$, $A3+3$, $G^{\underline{(3)}}$.

Order 1. LILIACEÆ. The flowers conform generally to the above formula, but 3 is replaced sometimes by 2 or 4: they are not zygomorphic; fruit a capsule or a berry.

Sub-order 1. LILIEÆ, with a loculicidal capsule, introrse anthers, and united styles.

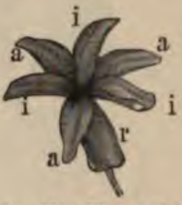


FIG. 178.—Flower of the Hyacinth: *a a a* the three outer; *i i i* the three inner segments of the perianth, which is tubular at the lower part (nat. size).

In a number of genera the six segments of the perianth cohere and form a tube which ends in six more or less deeply cut segments (Fig. 178): *e.g.*, *Hyacinthus orientalis*, the stem of which is an underground bulb (Fig. 14 *B*). Aloë has thick fleshy leaves; some species, as *Aloë soccotrina*, have a strong woody stem, and are shrubs, or almost trees.

There are also some among the very numerous genera in which the leaves of the perianth are distinct or cohere only for a very short distance from the base, which are of an aborescent habit; for instance, the species of Yucca, which are indigenous to Central America. The others have underground rhizomes or bulbs. These bulbs (see § 5 and Fig. 14 *B*) are, in fact, very short stems, covered with closely-packed cataphyllary leaves which are usually termed scales: so long as they are young, and not very vigorous, they send up only foliage leaves, which appear, year by year, above the ground; but in the course of years the axis itself of the bulb elongates and bears a terminal inflorescence. After the flowering is over, this axis dies down, and a lateral shoot is formed in the axil of one of the scales which may either become a new bulb, or it may at once develope into a flowering axis, the lowest cataphyllary leaves of which are bulb-scales. *Phormium tenax* (the New Zealand Flax) has ensiform leaves, about three feet in length, springing from the rhizome; their strong bast-fibres are used for various purposes. *Lilium candidum* is the white Lily. *L. bulbiferum*, which produces bulbils in the axils of the upper leaves, and *L. Martagon*, the Turk's cap Lily, have bulbs. *Fritillaria imperialis* is the Crown Imperial, the flowers of which are surmounted by a crown of leaves. *Tulipa Gesneriana* is the Tulip. *Scilla maritima* has a bulb which is not subterranean. Of Allium, several species are in cultivation for culinary purposes, as *A. Cepa*, the Onion; *A. ascalonicum*, the Shalot; *A. Schoenoprasum*, Chives; *A. porrum*, the common Leek; *A. sativum*, Garlic. The leaves of the various species of Allium are generally tubular and hollow; the flowers are disposed in spherical heads or umbels; bulbils are occasionally produced among the flowers.

Sub-order 2. Melanthieæ or Colchiceæ, with a septicidal capsule, usually extrorse anthers, and separate styles.

Tofieldia palustris has ensiform radical leaves; the flowers, which are pale green, are disposed in a raceme on a scape; it occurs in the north of England, in wet places on mountains, but it is rare. *Veratrum album* and *nigrum* have broad ovate leaves. *Colchicum autumnale* is the Autumn Crocus: when it is flowering in the autumn, the stem is underground; it is at this time short and

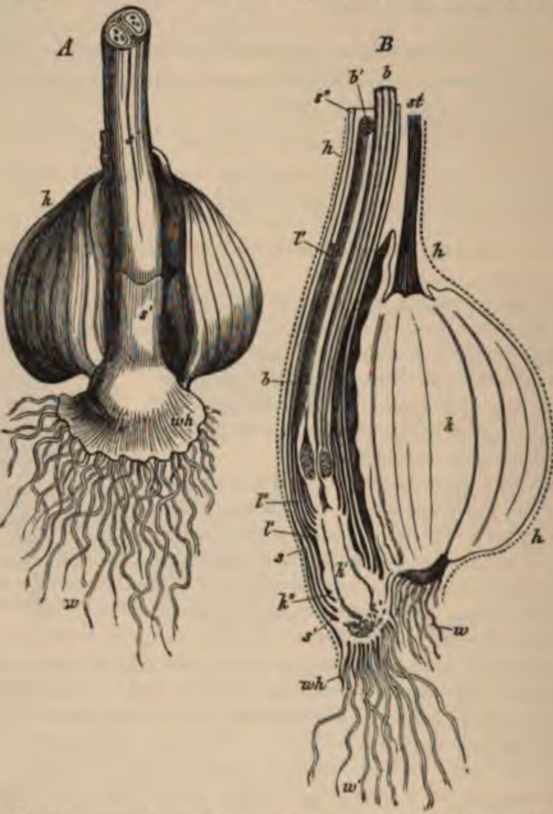


Fig. 179.—The underground part of a flowering plant of *Colchicum autumnale*. *A* Seen in front; *k* the corm; *s′ s″* cataphyllary leaves embracing the flower-stalk; *wh* its base, from which proceed the roots, *w*. *B* Longitudinal section: *h h* a brown membrane which envelops all the underground parts of the plant; *st* the flower and leaf-stalk of the previous year which has died down, its swollen basal portion (*k*) only remaining as a reservoir of food-materials for the new plant now in flower. The new plant is a lateral shoot from the base of the corm (*k*), consisting of the axis, from the base of which proceed the roots (*w*), and the middle part of which (*k′*) swells up in the next year into a corm, the old corm (*k*) disappearing; the axis bears the sheath-leaves (*s s′ s″*) and the foliage-leaves (*l′ l″*); the flowers (*b b′*) are placed in the axils of the uppermost foliage-leaves, the axis itself terminating amongst the flowers. (After Sachs.)

slender (Fig. 179 *k'*), attached laterally to the corm of the previous year's growth (*k*), and bears a few imperfectly developed leaves (*l' l''*) as well as one or two flowers (*b' b''*): the ovaries of the flowers are also subterranean; the six leaves of the perianth cohere and form a tube of some centimetres in length, which grows far beyond the ovaries and above the surface of the soil, terminating in a petaloid six-partite limb; the stamens are attached in the upper portion of the tube. In the spring the underground stem swells at its base (*k'*) into a corm, and grows upwards, so that the developing leaves (*l' l''*) and the capsule rise above ground; a lateral shoot is formed at its base, which, in the autumn, produces flowers, and this repeats the process.

Sub-order 3. Asparagineæ. The fruit is a berry; anthers introrse; styles united or distinct; in the flower the parts are sometimes in twos or fours, instead of in threes.

Dracæna Draco, the Dragon-tree, has a stem which grows in thickness; it is a native of the Canary Isles. *Asparagus officinalis* is the Asparagus; the young shoots, which spring from the underground rhizome, are eaten. *Convallaria majalis* is the Lily of the Valley. *Maianthemum bifolium* has a dimerous flower. The species of Smilax are creeping shrubs, the leaves of which have reticulated venation. *Ruscus aculeatus* (the Butcher's Broom), and other species, are small shrubs, with leaf-life branches (phylloclades), on which the diclinous flowers are borne in the axils of minute leaves. *Paris quadrifolia* (Herb Paris) is poisonous: the flowers are tetramerous, or exceptionally trimerous or pentamerous: they are terminal, and the stem beneath bears four (or three or five) leaves in a whorl beneath the flower (Fig. 180); the venation of the leaves is reticulate.

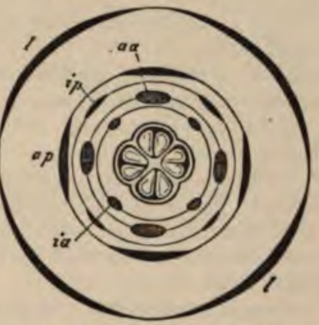


Fig. 180.—Diagram of the flower of *Paris quadrifolia*: *l* the foliage-leaves; *ap* the outer; *ip* the inner whorl of the perianth; *aa* outer; *ia* inner whorl of stamens. (After Sachs.)

Order 2. Juncaceæ. Floral formula, $K3$, $C3$, $A3 + 3$, $G^{(3)}$. Plants of a grass-like aspect; they differ from the preceding order in the dry and glumaceous character of the perianth. The leaves are linear or tubular; the inflorescence is an anthela (see p. 214).

The species of Luzula, which has a unilocular three-seeded ovary, *multiflora*, *pilosa*, *campestris*, and *sylvatica*, are common in woods and on heaths. *Juncus* has a trilocular many-seeded ovary; plants of this genus are called Rushes; *J. glaucus* and *effusus* have a tubular stem and leaves, and a terminal inflorescence which is displaced laterally by a tubular bract which appears to be a prolongation of the stem; they are common in wet fields; *J. bufonius*, by waysides.

Order 3. Pontederiaceæ. Water-plants of tropical America, with a zygomorphic petaloid perianth: in other respects they resemble the Liliaceæ.

SERIES II. EPIGYNÆ.

Ovary inferior.

Cohort 1. **Hydrales.** Order 1. HYDROCHARIDACEÆ. The flowers have a perianth, the inner whorl being petaloid, and usually conform to the monocotyledonous type, but with multiplication in the andrœcium and gynœcium; formula $K3$, $C3$, $A3 + 3 +$, $G_{\overline{(3 + \ldots)}}$. The flowers are usually diœcious the female flowers have staminodia; the male flowers have no gynœcium but an increased number of whorls in the andrœcium. The seed has no endosperm. Water-plants.

Tribe 1. *Hydrilleæ.* Ovary unilocular. Stem elongated, with whorls of small leaves.

Elodea (*Anacharis*) *canadensis* came originally from North America, and has spread in our waters so as even to impede navigation in canals.

Tribe 2. *Vallisnerieæ.* Ovary unilocular. Stem short, with crowded leaves.

Vallisneria spiralis inhabits the lakes and ditches of the warmer parts of Europe. The leaves are long, narrow, and linear. The female flowers are raised above water on long peduncles; the male inflorescences break away from their peduncles and float about on the water to fertilise the female flowers; the fruit ripens under water.

Tribe 3. *Stratiotideæ.* Ovary 6- (or more) chambered. Stem short, with crowded leaves.

Stratiotes aloides (Water Soldier) has stiff narrow leaves. *Hydrocharis Morsus Ranæ* (Frog's bit) is diœcious; the plant is small and floats on the water, with small roundly-cordate leaves.

Cohort 2. **Dioscorales.** Flowers regular: floral formula $K3$, $C3$, $A3 + 3$, $G_{\overline{(3)}}$: fruit a berry or a capsule.

Order 1. DIOSCOREÆ. The ovary is trilocular, with one or two ovules in each loculus: the flowers are diœcious. They are climbing plants, with large above- or underground tubers, and usually triangular leaves, with reticulate venation.

Dioscorea sativa, *Batatas* and others, known as Yams, are largely cultivated in the tropics as a food rich in starch. *Tamus communis*, the Black Bryony, is common in England.

Order 2. TACCACEÆ. The ovary is unilocular and many-seeded. The flowers are hermaphrodite. They are tropical herbs, and the leaves which spring from the subterranean rhizome have reticulated venation.

Order 3. Bromeliaceæ. $K3$, $C3$, $A3 + 3$, $G\,(3)$. The ovary is superior, inferior, or semi-inferior, trilocular, with many seeds The segments of the calyx are sepaloid, those of the corolla petaloid. The leaves are usually long and narrow, sharply serrate; the stem is generally very short. The flowers are hermaphrodite, and form spikes or panicles with bracts.

Ananassa sativa (Ananas, Pine-apple). The fruit is a berry, and the berries of each inflorescence coalesce into a spurious fruit (sorosis), above which the axis of the inflorescence extends and bears a crown of leaves. In a state of cultivation the berries contain no seeds. It is a native of America, and is cultivated in all warm countries and in hot-houses.

Cohort 3. **Amomales** (Scitamineæ) The flowers are zygomorphic or asymmetrical: general formula, $\downarrow K3$, $C3$, $A3 + 3$, $G_{\overline{(3)}}$, occasionally with a great reduction in the andrœcium. Perianth wholly petaloid, or the calyx may be sepaloid; ovary trilocular. Fruit, a capsule or a berry. Usually no endosperm, but abundant perisperm. They are tall herbaceous plants; the leaves are large and have pinnate venation.

Order 1. Musaceæ. $\downarrow K3$, $C3$, $A3 + 2$, $G_{\overline{(3)}}$. Perianth petaloid, irregular; the anterior external member is usually very large, and the posterior always very small; in Musa the five anterior members of the perianth are connate, forming a tube which is open posteriorly: the posterior stamen is sterile or absent, and the others are not always fertile. The sub-family of Heliconieæ differs from this type in the structure of the flower. They are all shrubs of colossal growth, with enormously long leaves: the flowers are usually arranged in spicate inflorescences in the axils of large and often coloured bracts; sometimes several flowers spring from the axil of one bract.

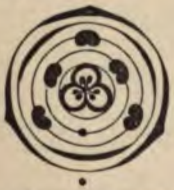


Fig. 181.—Diagram of flower of Musa.

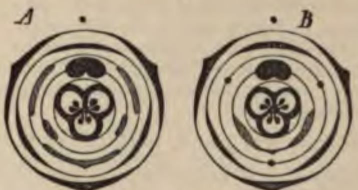


Fig. 182.—Diagram of the flower of Zingiberaceæ. *A* Hedychium. *B* Alpinia.

Musa paradisiaca (Plantain), *M. Sapientium* (Banana), and *M. Ensete* are natives of the tropics of the Old World; the two former are now distributed throughout America and applied to a great variety of purposes; the fruit, which is of the nature of a berry, is an article of food, and the fibro-vascular bundles are used for making textile fabrics.

Order 2. ZINGIBERACEÆ. $\psi\, K3, C3, A\dagger 3 + 1 \dagger 2, G_{\overline{(3)}}$. Perianth zygomorphic. The three outer staminodes are connate, forming a leaf-like three-lobed body, the *labellum*, the anterior median lobe being much the largest. Of the inner whorl of stamens the posterior alone bears a perfect anther, the other two being transformed into small glandular bodies. The flower of Alpinia (Fig. 182 *B*) differs somewhat from this type in its structure. There is a small amount of endosperm in the seed, in a depression in the perisperm.

The starch which is prepared from the rhizome of *Curcuma angustifolia* and *leucorrhiza* is known in commerce as East Indian arrowroot.

Order 3. MARANTACEÆ or CANNACEÆ. $\psi\, K3, C3, A\dagger 1$ or $2 + 1 \dagger 2, G_{\overline{(3)}}$. The andrœcium is represented by a number of petaloid bodies, of which one only, the posterior stamen of the inner whorl, bears a unilocular anther (Fig. 183 *st an*); of the staminodia one is larger than the others, and is reflexed, forming a *labellum* (Fig. 183 *l*); the narrow ones vary in number in the different species (Fig. 183 α and β).

Canna indica and other species are commonly grown as ornamental plants.

Amylum Marantæ, the starchy meal prepared from the rhizome of *Maranta arundinacea*, is true or West Indian arrowroot.

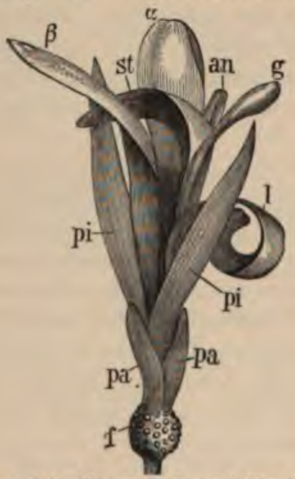


FIG. 183.—Flower of *Canna indica* (nat. size): *f* inferior ovary; *pa* the outer; *pi* the inner whorl of the perianth; *g* style; *st* the fertile stamen, with (*an*) the anther; *l* labellum; α and β the two staminodia. (After Eichler.)

Cohort 4. **Orchidales**. Flowers zygomorphic, reduced in the andrœcium which is adherent to the gynœcium: perianth petaloid. Formula, $\psi\, K3, C3, A1 + 2, G_{\overline{(3)}}$. Seeds very small, without endosperm or perisperm; the embryo a minute undifferentiated mass of cells.

Order 1. ORCHIDEÆ. The flowers of most of the genera have the formula $\psi\, K3, C3, A1 + \dagger 2, G_{\overline{(3)}}$: those of Cypripedium, however, have the formula $\psi\, K3, C3, A \dagger 1 + 2, G_{\overline{(3)}}$ (Fig. 184 *A*, *B*). In consequence of torsion of the ovary the flower is generally so placed that the posterior side of the flower, instead of being uppermost, as is usually the case, comes to lie inferiorly (*resupinate*). The posterior segment (petal) of the inner whorl, called the *labellum* (Fig. 185, see also Fig. 155 *l*), is always larger than the others, and varies greatly in form; it frequently has a spur (Fig. 185 *sp*) or a sac-shaped cavity (Fig. 155). The filaments of the three stamens adhere to the three styles; they together form the *gynostemium* (Fig. 155 *S*, Fig. 187 *B* and *C gs*). The fertile stamen bears a bilocular anther which, by the absorption of the septum often appears to be unilocular, and in rare cases is quadrilocular; the other two members of the andrœcium are staminodia (Fig. 155 *x*) and sometimes are only represented as small tooth-like prominences (Fig. 184). In some genera the pollen-grains are separate from each other, in others they occur in groups of four (tetrads), and in the majority they are united into a mass which fills an entire pollen-sac (Fig. 185 *p*, 155 *p*). In the latter case pollination is always effected by the agency of insects; the two pollen-masses (*pollinia*) become attached to the proboscis of the insect by means of a sticky part of the stigma, the *rostellum* (Fig. 155 *h*), and are conveyed to another flower on the stigma of which they are deposited. In many foreign forms these arrangements for cross-fertilisation are much more complicated. The ovary is unilocular; it contains numerous anatropoüs parietal ovules.

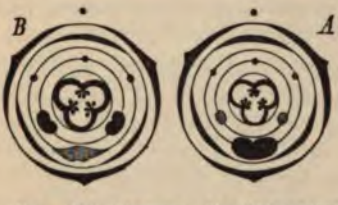


FIG. 184.—Diagram of Orchidaceous flowers. *A* The usual type. *B* Cypripedium; the shaded stamens are staminodia.

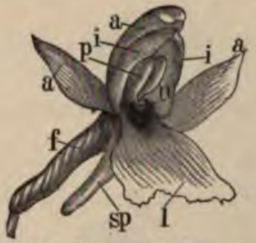


FIG. 185.—Flower of *Orchis mascula* (2 ×): *f* the twisted ovary; *a a a* the three outer perianth leaves; *i i* two of the inner; *l* the third inner perianth leaf, the labellum, with (*sp*) the spur; *n* stigma; *p* pollen-sacs.

The indigenous species have underground rhizomes or tubers. Two tubers are usually present: the older one, which, at the time of flowering, becomes flaccid (Fig. 186 *A* and *B*, 1), throws up the flowering scape (Fig. 186 *s*) or, in young plants, a short underground stem which produces only leaves above ground. At the upper end of this tuber another much firmer tuber is formed (Fig. 186, 2), bearing at its apex the bud of the next year's stem (*K*). The tuber is to be regarded as a lateral bud which coalesces with its first root (or more than one, Fig. 186 *B*) and then increases in size. The lower end of an undivided tuber, as well as the ends of palmate tubers, has, in the young state at least, the same structure as the apex of a true root.

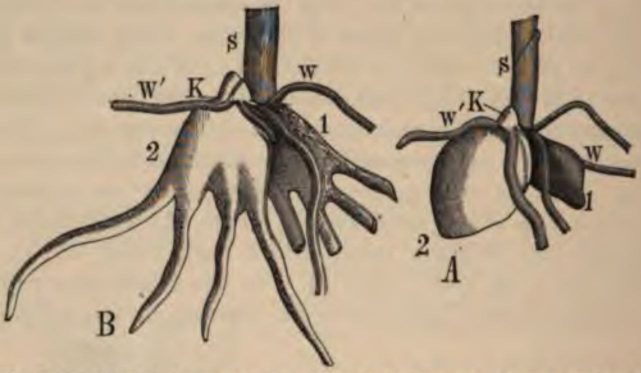


FIG. 186.—Tubers (*A*) of *Orchis morio*; B of *Gymnadenia conopsea*: *s* the peduncle; 1 this year's tuber; 2 next year's tuber; *k* the bud; *w* and *w′* roots (nat. size).

Orchis Morio, and *militaris* have round or oval tubers (Fig. 186 *A*), *O. latifolia* and *incarnata* have palmate tubers running out into roots (Fig. 186 *B*); they occur in damp meadows. *Gymnadenia conopsea* has long spikes of flowers and palmate tubers; it occurs in woods and on heaths. *Ophrys muscifera*, *apifera*, and *aranifera* have flowers resembling insects; they occur, but are not common, on chalk pastures. *Cephalanthera rubra*, *Epipactis latifolia*, and others, have creeping rhizomes; they are found in woods. *Corallorrhiza innata* has a coral-like, branched, underground rhizome, with no roots. *Epipogium Gmelini* has likewise no roots; both these forms are devoid of chlorophyll, and grow on humus in forests. *Neottia Nidus-avis* also is without chlorophyll, and lives on humus in woods; it has a fleshy rhizome thickly beset with roots which grow in a tangled mass like a bird's nest. *Cypripedium Calceolus*, the Lady's Slipper, grows in mountain-woods; it has a creeping rhizome and broad ovate leaves; the perianth is of a reddish-brown colour, except the labellum, which is yellow, and forms an inflated sac. The whole structure of the flower

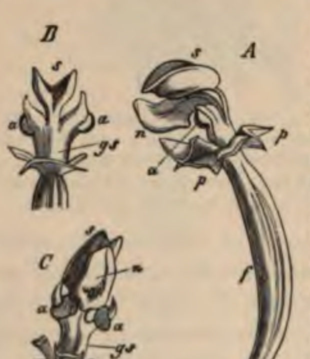


FIG. 187.—Flower of *Cypripedium Calceolus*: *p p* the leaves of the perianth have been cut away. *A* Side view. *B* Back view. *C* Front view; *f* ovary; *gs* gynostemium; *a a* the two fertile stamens; *s* staminode; *n* stigma. (After Sachs.

is unlike that above described as typical for most of the genera; the two stamens, which in other genera are reduced to staminodia, are fertile (Fig. 187, *a*, *a*, and comp. Fig. 184), and the anterior stamen, which in most cases is the only fertile one, is here a large staminode (Fig. 187 *s*).

A still greater variety of forms is found among the tropical genera and species, which for the most part grow upon trees (epiphytic) and throw out large aërial roots. *Vanilla planifolia* and other species have a long pod-like fruit which is well known for its perfume and flavour, as Vanilla. Vanda, Oncidium, Phajus, and other genera are extensively cultivated in hothouses for their beautiful and often fragrant flowers.

Cohort 5. **Narcissales.** Fowers regular or zygomorphic: not less than three stamens in the andrœcium: perianth petaloid: seeds with endosperm.

Order 1. AMARYLLIDEÆ. $K3, C3, A3 + 3$, or 12 to 18, $G_{\overline{(3)}}$. The flower is occasionally zygomorphic and narrowly funnel-shaped: anthers introrse. The fruit is usually a trilocular loculicidal capsule, sometimes a berry.

Alstrœmeria has a leafy stem and the habit of the Lily. The other genera have a very short, sometimes bulbous stem, and a long floral axis. *Amaryllis formosa* is an ornamental plant, with large tubular funnel-shaped, unequally toothed flowers. *Galanthus nivalis* is the Snowdrop; *Leucojum vernum*, the Snowflake. *Narcissus pseudo-Narcissus* (the Daffodil), *poeticus*, and other species are favourite garden plants. The ligulæ of the six segments of the perianth cohere to form the tubular corona. *Agave americana*, commonly known as the false Aloe, is a native of Mexico, but has been naturalized in Southern Europe. The short stem bears a large rosette of very thick and prickly leaves; when it has attained a sufficient vigour — in Southern Europe, after from ten to twenty years—it throws up an axis of some yards in length, which branches very much, and bears a large number of flowers, which are arranged somewhat in the form of a pyramid.

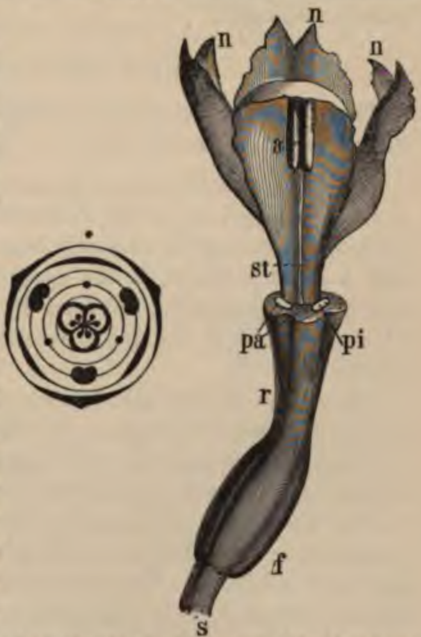


FIG. 188.—Diagram of the flower of Iris, and view of the same after the removal of the perianth: *s* peduncle; *f* inferior ovary; *r* tubular portion of the perianth; *pa* the insertion of the outer, *pi* of the inner leaves of the perianth; *st* stamens; *a* anther; *n n n* the three petaloid stigmas (nat. size).

Order 2. IRIDEÆ. $K3$, $C3$, $A3+0$, $G_{\overline{(3)}}$. The flower is sometimes zygomorphic: anthers extrorse: the fruit is a trilocular loculicidal capsule.

Iris, the Flag, has a horizontal underground rhizome, which throws up leaves which are expanded in their median plane, and scapes which bear the flowers. The stigmas assume a petaloid aspect, and by their concave outer surfaces cover over the stamens which are opposite to and below them (Fig. 188).

Iris pumila, germanica, and others are favourite garden plants. *I. pseudacorus*, the Yellow Flag, is common in ditches. Gladiolus has an underground bulbous stem and a tall, many-flowered scape; the flowers are usually zygomorphic; *G. communis* (*illyricus*) occurs wild in England. Crocus, from which saffron is obtained, has an underground corm, from which grows a very short underground stem; this bears the leaves which rise above the ground, and terminates in a flower, the ovary of which is subterranean: the tube of the perianth spreads out above the ground into a six-partite limb, at the base of which the three stamens are inserted.

CLASS X.—DICOTYLEDONS.

The embryo has two opposite cotyledons; the endosperm is frequently absorbed before the seed is ripe.

The ripe seed sometimes contains a large mass of endosperm and a small embryo, as in the Umbelliferæ and Euphorbiaceæ; frequently the embryo is relatively large and the endosperm occupies only a small space, as in the Labiatæ; or, finally, the endosperm may be wholly wanting, and then the embryo fills the whole cavity of the testa, as in the Horse-chestnut, the Leguminosæ, and the Compositæ.

The *embryo* usually has distinct members, consisting of an axis and two opposite cotyledons; in rare cases, *e.g.*, Corydalis, only one cotyledon is present, or abnormally three may occur, as is occasionally the case in the Oak and Almond. The cotyledons usually constitute the greater portion of the embryo, as in the Leguminosæ (Fig. 189 *A c*) and the Horse-chestnut, where they are thick and fleshy. The stem (*caulicle*) bears at its apex above the cotyledons either a bud consisting of several leaves (*plumule*), as in Vicia (Fig. 189 *Kn*), or it is naked. In parasites and saprophytes which are devoid of chlorophyll, and which have very small seeds, such as Pyrola and Orobanche, the embryo is quite undifferentiated, and it consists of only a small number of cells.

On germination, after the testa is ruptured, the hypocotyledonary portion of the axis elongates so as to push the root out of the seed;

the root immediately begins to grow rapidly and attains a considerable length (Fig. 189 *B h*), whilst the remainder of the embryo is still contained in the seed. The cotyledons may either remain enclosed in the seed during the whole process of germination, and perish so soon as the nutritious substances contained in them have been absorbed by the plant (*e.g.*, Horse-chestnut and Vicia, Fig. 189), their petioles at the same time elongating so that the plumule, which at first is bent inwards, is pushed out and subsequently becomes erect; or, as is more generally the case, the cotyledons escape from the testa (Fig. 190), become green, and act as the first leaves of the young plant.

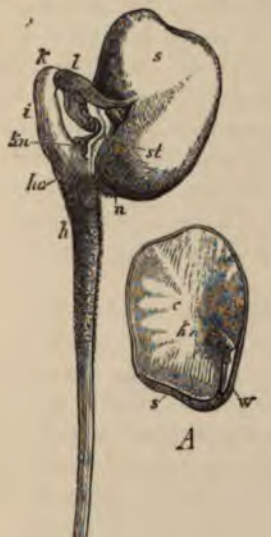


FIG. 189.—*Vicia Faba*, the Bean. *A* Seed with one of the cotyledons removed; *c* the remaining cotyledon; *w* radicle; *kn* plumule; *s* testa. *B* Germinating seed; *s* testa; *l* a portion of the testa torn away; *n* hilum; *st* petiole of one of the cotyledons; *k* curved epicotyledonary portion of the axis; *hc* the very short hypocotyledonary portion of the axis; *h* the primary root; *ws* its apex; *kn* bud in the axil of one of the cotyledons.

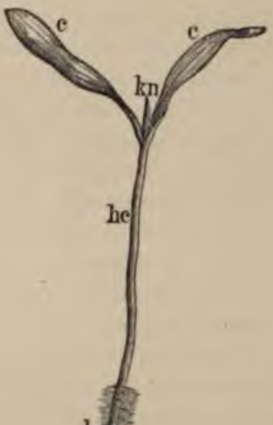


FIG. 190.—Seedling of the Maple (nat. size): *c c* the cotyledons; *kn* the plumule; *hc* the hypocotyledonary portion of the axis; *w* primary root; *h* root-hairs. (the lower part is cut off).

The axis of the embryo frequently persists as the main axis of the plant, which grows in length and produces numerous less vigorous lateral shoots; but it often happens that some of these lateral branches subsequently grow as vigorously as the main axis: when this is the case, and when also the lower and feebler shoots die off, a head, such as is common in forest-trees, is the result; in the case of shrubs, vigorous branches are formed quite low down on the main stem. In many forest-trees the stem (trunk) and branches form a sympodium, the uppermost lateral bud growing each year in the direction of the main axis, which does not itself develope any further (§ 6); besides these there are many and very various arrangements by means of which the life of the individual is transferred to new lateral shoots; such as the formation of rhizomes, runners, tubers, and sometimes of bulbs, on stems and roots. When the axis of the embryo continues to be the main axis of the plant, the primary root also developes greatly, and forms a tap-root from which the lateral roots grow in acropetal succession; in cases in which the growth in length of the tap-root is limited, numerous adventitious roots spring from its older portions; these may again give rise to lateral roots, and by a repetition of this process an elaborate root-system is formed.

The fibro-vascular bundles of the stem are almost always open, and the growth in thickness of the stem is effected by the activity of the cambium-ring which is formed (§ 26). In certain cases, there are, in addition to these fibro-vascular bundles which together form a ring, other isolated bundles which traverse the stem longitudinally, as in Begonia and Aralia; even more complicated modifications in the arrangement of the bundles occur in Piperaceæ, Sapindaceæ, Menispermaceæ, Phytolacca, etc.

The branching of the stem is invariably monopodial (§ 6) and almost always axillary. Those cases in which, as, for instance, in the racemes of the Cruciferæ, the bracts are suppressed, are obviously not exceptions to this rule.

The leaves exhibit infinite variety both in their relative position and in their form. The foliage-leaves almost always consist of petiole and blade; sheaths which surround the stems are comparatively rare, but stipules, on the contrary, are very common. Branching or segmentation of the leaves is common and is frequently indicated by the incision of the margin. The venation of the leaves is characterized by the presence of a large number of veins which project on the under surface, except in thick fleshy leaves, and which frequently anastomose; a midrib is almost always present, giving off lateral branches to right and left.

The flowers, when they are lateral, are usually furnished with two bracteoles: they differ very considerably in their structure and cannot be referred to any one type. The following are the principal forms:

1. In a considerable number the perianth, which is simple, and the andrœcium are isomerous, consisting of four, five, or six members; their arrangement is either spiral ($\frac{2}{5}$), or whorled so that the stamens are always superposed on the leaves of the perianth; the latter are all similar and are sepaloid. Formula $P5 \mid A5$, or $Pn + n$, $An + n$, where $n = 2$ or 3. This structure prevails in some of the Monochlamydeæ (Urticales, Amentales, Quernales).

2. In a second group, all the parts of the flower are arranged in a continuous spiral: the perianth may consist only of a calyx, or a corolla may be developed in place of the external stamens; when this is the case it alternates with the calyx, provided that it is isomerous with it, as in most Ranales.

3. With these two types are connected by many intermediate forms those flowers in which the biseriate perianth and the stamens are in whorls; their formula is Kn, Cn, $An + n$, where n usually = 5 or 4. This is the most common type of the structure of the flower; it occurs in most Polypetalæ and Gamopetalæ; it may be modified either by the suppression of one (usually the inner) whorl of stamens, or by their multiplication, their branching, or their cohesion, or by the suppression of the corolla.

4. Finally, there remain certain flowers which cannot be directly referred to either of the above types, and they must therefore be left unexplained for the present, and the relationships of their families must remain uncertain.

The sub-divisions in which the Dicotyledons are arranged in the following classification are especially characterized by peculiarities in the structure of the flower. It is impossible, however, to draw sharp distinctions between the sub-divisions, the orders, and sometimes even between the families, for the position of a plant in the system depends not upon any one character, but upon the aggregate of its characters.

SUB-CLASS I. MONOCHLAMYDEÆ.

SERIES I. HYPOGYNÆ.

Cohort 1. **Piperales.**
Order 1. Piperaceæ.
Cohort 2. **Urticales.**
Order 1. Urticeæ.
„ 2. Moreæ.
„ 3. Cannabineæ.
„ 4. Ulmaceæ.
„ 5. Plataneæ.
„ 6. Ceratophylleæ.
Cohort 3. **Amentales.**
Order 1. Betulaceæ.
„ 2. Myricaceæ.
„ 3. Casuarineæ.
„ 4. Salicineæ.
Cohort 4. **Euphorbiales.**
Order 1. Euphorbiaceæ.
„ 2. Buxineæ.
Cohort 5. **Daphnales.**
Order 1. Thymelæaceæ.
„ 2. Elæagnaceæ.
„ 3. Proteaceæ.
„ 4. Laurineæ.
„ 5. Myristiceæ.
Cohort 6. **Chenopodiales.**
Order 1. Chenopodiaceæ.
„ 2. Amarantaceæ.
„ 3. Phytolaccaceæ.
„ 4. Nyctagineæ.
„ 5. Polygoneæ.
Cohort 7. **Nepenthales.**
Order 1. Nepentheæ.

SERIES II. EPIGYNÆ.

Cohort 1. **Quernales.**
Order 1. Juglandeæ.
„ 2. Corylaceæ.
„ 3. Cupuliferæ.
Cohort 2. **Asarales.**
Order 1. Aristolochieæ.
„ 2. Cytinaceæ.
Cohort 3. **Santalales.**
Order 1. Santalaceæ.
„ 2. Loranthaceæ.
„ 3. Balanophoreæ.

SUB-CLASS II. GAMOPETALÆ.

SERIES I. HYPOGYNÆ.

Cohort 1. **Lamiales.**
Order 1. Labiatæ.
„ 2. Verbenaceæ.
„ 3. Globularieæ.
„ 4. Plantagineæ.
Cohort 2. **Personales.**
Order 1. Scrophularineæ.
„ 2. Bignoniaceæ.
„ 3. Acanthaceæ.
„ 4. Gesneraceæ.
„ 5. Orobancheæ.
„ 6. Lentibularieæ.

Cohort 3. **Polemoniales.**
Order 1. CONVOLVULACEÆ.
„ 2. CUSCUTEÆ.
„ 3. POLEMONIACEÆ.
„ 4. SOLANACEÆ.
„ 5. BORAGINEÆ (ASPERIFOLIÆ).

Cohort 4. **Gentianales.**
Order 1. GENTIANEÆ.
„ 2. LOGANIACEÆ.
„ 3. APOCYNEÆ.
„ 4. ASCLEPIADEÆ.
„ 5. OLEACEÆ.
„ 6. JASMINEÆ.

Cohort 5. **Ebenales.**
Order 1. SAPOTEÆ.
„ 2. EBENACEÆ.
„ 3. STYRACEÆ.

Cohort 6. **Primulales.**
Order 1. PRIMULACEÆ.
„ 2. MYRSINEÆ.
„ 3. PLUMBAGINEÆ.

Cohort 7. **Ericales.**
Order 1. ERICACEÆ.
„ 2. EPACRIDEÆ.
„ 3. RHODORACEÆ.
„ 4. PYROLACEÆ.
„ 5. MONOTROPEÆ.
„ 6. VACCINIEÆ.

SERIES II. EPIGYNÆ.

Cohort 1. **Campanales.**
Order 1. CAMPANULACEÆ.
„ 2. LOBELIACEÆ.

Cohort 2. **Asterales.**
Order 1. VALERIANEÆ.
„ 2. DIPSACEÆ.
„ 3. COMPOSITÆ.

Cohort 3. **Rubiales.**
Order 1. RUBIACEÆ.
„ 2. CAPRIFOLIACEÆ.

SUB-CLASS III. POLYPETALÆ.

SERIES I. CALYCIFLORÆ.

Cohort 1. **Umbellales.**
Order 1. UMBELLIFERÆ.
„ 2. ARALIACEÆ.
„ 3. CORNACEÆ.

Cohort 2. **Ficoidales.**
Order 1. CACTEÆ.
„ 2. AIZOACEÆ (FICOIDEÆ).

Cohort 3. **Passiflorales.**
Order 1. PASSIFLORACEÆ.
„ 2. PAPAYACEÆ.
„ 3. BEGONIACEÆ.
„ 4. CUCURBITACEÆ.

Cohort 4. **Myrtales.**
Order 1. ONAGRACEÆ.
„ 2. LYTHRARIEÆ.
„ 3. MYRTACEÆ.
„ 4. RHIZOPHORACEÆ.

Cohort 5. **Rosales.**
Order 1. ROSACEÆ.
„ 2. LEGUMINOSÆ.
„ 3. CRASSULACEÆ.
„ 4. SAXIFRAGACEÆ.
„ 5. DROSERACEÆ.
„ 6. HAMAMELIDEÆ.
„ 7. HALORAGIDEÆ.
„ 8. HIPPURIDEÆ.
„ 9. CALLITRICHINEÆ.

SERIES II. DISCIFLORÆ.

- Cohort 1. **Sapindales.**
  - Order 1. SAPINDACEÆ.
  - „ 2. ACERINEÆ.
  - „ 3. TEREBINTHACEÆ (ANACARDIACEÆ).
  - „ 4. STAPHYLEACEÆ.
- Cohort 2. **Celastrales.**
  - Order 1. CELASTRINEÆ.
  - „ 2. RHAMNEÆ.
  - „ 3. AMPELIDEÆ.
- Cohort 3. **Olacales.**
  - Order 1. ILICINEÆ (AQUIFOLIACEÆ).
  - „ 2. EMPETREÆ.
- Cohort 4. **Geraniales.**
  - Order 1. GERANIACEÆ.
  - „ 2. LINEÆ.
  - „ 3. ERYTHROXYLEÆ.
  - „ 4. OXALIDEÆ.
  - „ 5. BALSAMINEÆ.
  - „ 6. TROPÆOLEÆ.
  - „ 7. ZYGOPHYLLEÆ.
  - „ 8. RUTACEÆ.
  - „ 9. MELIACEÆ.
  - „ 10. SIMARUBEÆ.
  - „ 11. BURSERACEÆ.

SERIES III. THALAMIFLORÆ.

- Cohort 1. **Malvales.**
  - Order 1. TILIACEÆ.
  - „ 2. STERCULIACEÆ.
  - „ 3. MALVACEÆ.
- Cohort 2. **Guttiferales.**
  - Order 1. HYPERICINEÆ.
  - „ 2. ELATINEÆ.
  - „ 3. TERNSTRŒIMACEÆ.
  - „ 4. CLUSIACEÆ (GUTTIFERÆ).
  - „ 5. DIPTEROCARPEÆ.
- Cohort 3. **Caryophyllinæ.**
  - Order 1. CARYOPHYLLACEÆ.
  - „ 2. PORTULACACEÆ.
  - „ 3. TAMARISCINEÆ.
- Cohort 4. **Polygalinæ.**
  - Order 1. POLYGALACEÆ.
  - „ 2. PITTOSPOREÆ.
- Cohort 5. **Parietales.**
  - Order 1. PAPAVERACEÆ.
  - „ 2. FUMARIACEÆ.
  - „ 3. CRUCIFERÆ.
  - „ 4. CAPPARIDEÆ.
  - „ 5. RESEDACEÆ.
  - „ 6. CISTINEÆ.
  - „ 7. BIXACEÆ.
  - „ 8. VIOLARIEÆ.
  - „ 9. SARRACENIACEÆ.
- Cohort 6. **Ranales.**
  - Order 1. RANUNCULACEÆ.
  - „ 2. MAGNOLIACEÆ.
  - „ 3. CALYCANTHACEÆ.
  - „ 4. NYMPHÆACEÆ.
  - „ 5. MENISPERMACEÆ.
  - „ 6. BERBERIDEÆ.

SUB-CLASS I. MONOCHLAMYDEÆ.

The flowers usually have a simple sepaloid perianth, or it may be absent; they are usually diclinous.

SERIES I. HYPOGYNÆ.

Ovary superior.

Cohort 1. **Piperales.** The flowers are usually hermaphrodite, and they are arranged in a spike or a spadix, with bracts; perianth usually absent. Ovule orthotropous, solitary, basal, or suspended; in rare cases there are several parietal ovules. The embryo is small and lies imbedded in endosperm, in a depression of the abundant perisperm.

Order 1. PIPERACEÆ. Ovary unilocular, with a single orthotropous, erect, central ovule. The inflorescence is a long spadix, with peltate subtending bracts (Fig. 191 *f*, *below*), in the axils of which the flowers are situated. The flower consists only of an ovary (Fig. 191 *f*, *above*) and six, three, or sometimes two stamens; the fruit is a berry.

Piper nigrum is a climbing shrub belonging to the East Indies; the unripe dried fruits are black pepper; white pepper consists of the ripe fruits of the same plant, which, after maceration, are freed from their outer coat.

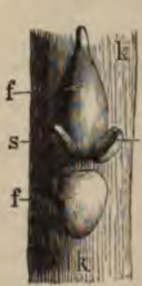


FIG. 191.—Part of the spadix of Piperomia, with a flower: *f* (below) the subtending bract; *s s* the two stamens; *f* (above), ovary; *k* surface of the spadix (mag.).

Cohort 2. **Urticales.** Flowers usually diclinous, in inflorescences of various forms: perianth usually present, simple, sepaloid, consisting of five or four (2 + 2) segments; stamens opposite to the segments of the perianth excepting in the Plataneæ (Order 5); ovary monomerous, usually unilocular, a second rudimentary carpel being usually present in the form of a second style; ovule solitary, in different positions. Seed commonly containing endosperm. The inflorescences in Orders 1–3 are usually situated two together at the base of a modified shoot which springs from the axil of a leaf, and they are cymose (Fig. 192). The leaves are generally hirsute.

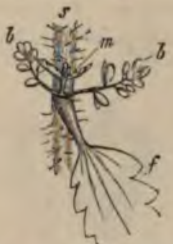


FIG. 192.—Part of the stem of *Urtica urens*, with a leaf (*f*), in the axil of which is the branch (*m*), at the base of which are the inflorescences (*b*), without any bracts (nat. size).

Order 1. URTICEÆ. Ovule central, orthotropous, erect. Seed containing endosperm. They are mostly herbs or shrubs without milky juice and frequently provided with stinging-hairs: leaves alternate, stipulate. Flowers polygamous, monœcious, or diœcious, in paniculate or glomerulate inflorescences.

Urtica urens and *dioica* (Stinging Nettles) are known by the stinging hairs which are distributed over their whole surface: the two outer segments of the perianth of the female flower are larger than the inner segments (Fig. 193 *B*). In the former species the male and female flowers are contained in the same panicle, and the floral axis is but feebly developed; in the latter they are on different plants, and the axis is well developed and bears leaves. *Böhmeria nivea*, a native of China and Japan, has strong bast-fibres used for weaving the material known in England as Grass-cloth. *Parietaria erecta*, having polygamous flowers with a gamophyllous perianth, and destitute of stinging-hairs, occurs occasionally on walls, by roadsides, etc.

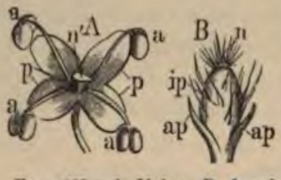


FIG. 193.—*A* Male; *B* female flowers of the Stinging Nettle, Urtica: *p* perianth; *a* stamen; *n′* rudimentary ovary of the male flower; *ap* outer; *ip* inner whorl of the perianth; *n* stigma of the female flower (mag.).

Order 2. MOREÆ. Ovule suspended, anatropous or campylotropous, more rarely basal and orthotropous: seed with or without endosperm; the fruit is enveloped by the perianth, which becomes fleshy, or by a fleshy floral axis. Trees and shrubs with milky juice, scattered leaves and deciduous stipules.

Morus alba and *nigra* (Mulberry) come from Asia; the flowers are disposed in short catkins; the catkins are borne singly on shoots which, at the time of flowering, are still buds, and they contain flowers of one sex only (but the flowers are monœcious); the female flowers give rise, as ripening takes place, to a spurious fruit (sorosis), consisting of spurious drupes formed by the perianths. The leaves, particularly of the former species, are the food of the silk-worm. *Broussonetia papyriferia* (Paper Mulberry) has flowers like the preceding, but they are diœcious. The bark is made into paper in China and Japan. *Maclura tinctoria*, in Central America, yields Fustic, a dye. *Ficus Carica* is the Fig-tree of Southern Europe; the fig itself (termed a syconus) is the deeply concave axis of the inflorescence, on the inner surface of which the flowers and subsequently the fruits, in the form of hard grains (achenes), are borne (Fig. 194 *m f*); the cavity is closed above by small bracts (Fig. 194 *b*). *Ficus elastica* is the Indian-rubber tree; it is frequently cultivated in rooms. *F. religiosa* and other East Indian species yield Caoutchouc, which is their inspissated milky juice (latex). *Artocarpus incisa* is the Bread-fruit tree of the South Sea Islands; the large spurious fruit (sorosis) of this tree is roasted and eaten as bread. *Galactodendron utile*, the Cow-tree of Columbia, has a nutritious latex, while that of *Antiaris toxicaria* (Java) is poisonous.

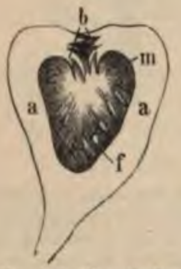


FIG. 194.—Longitudinal section of a Fig (nat. size): *a a* fleshy axis of the inflorescence; *f* female; *m* male flowers; *b* bracts.

Order 3. CANNABINEÆ. Ovule suspended, campylotropous.

Flowers diœcious, in panicled inflorescences. The male flowers (Fig. 195 *A*) have a 5-partite perianth and 5 short stamens; the female flowers have a tubular entire perianth (Fig. 195 *B p*) enclosed in a bract (Fig. 195 *B d*). Herbs with decussate leaves—at least the lower ones—and persistent stipules; devoid of latex.

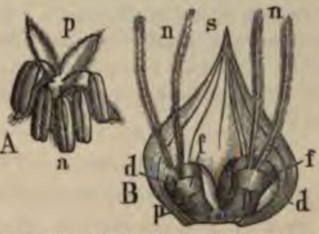


FIG. 195.—*A* Male flower of the Hop: p the perianth; *a* stamens. *B* Female flower: *p* perianth; *f* ovary, with two stigmas (*n*); each flower is enclosed in its bract (d); *s* scale, *i.e.*, one of the two stipules, from the common axil of which the branch bearing the flowers springs.

Cannabis sativa, the Hemp, is a native of Asia, cultivated throughout Europe. The male inflorescences are panicled dichasia or scorpioid cymes, and are disposed on both sides of a rudimentary shoot at the apex of the plant; the female flowers are placed singly on both sides of a similar shoot, which bears secondary shoots in the axils of its leaves, each having two flowers. The tough bast-fibres are used in weaving and for ropes; the seeds contain a great deal of oil. *Humulus Lupulus*, the Hop, is both cultivated and found wild. The stem, which has the peculiarity of twining to the right, bears its leaves in pairs, each of which has two pairs of membranous stipules. In the inflorescence the bracts are placed singly, and are finally represented only by their stipules. In the female inflorescence, which has the appearance of a fir-cone, a rudimentary shoot is present in the axil of each pair of stipules which bears two flowers on each side; it seems at first sight as if two flowers were developed in the axil of each stipule (Fig. 195 *B*). All the bracts are covered, especially on the upper surface, with numerous yellow glands. In the male inflorescence the shoot which bears the flowers is well developed.

Order 4. ULMACEÆ. Ovule suspended and solitary. Flowers mostly hermaphrodite, with a 4–6-partite perianth (Fig. 196 *A*). Woody plants devoid of milky juice: leaves alternate, with deciduous stipules. The inflorescences (glomerules) are borne directly in the axils of the leaves.

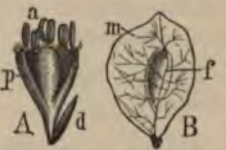


FIG. 196.—*A* Flower of *Ulmus campestris* (mag.): *d* bract; *p* perianth; *a* stamens. *B* Fruit (samara) (nat. size): *m* membranous margin (wing).

In the genus Ulmus the hermaphrodite flowers are fascicled in the axils of the leaves of the previous year, and they are invested by bud-scales; one or more flowers are developed in the axil of the innermost scale before the opening of the leaves. The ovary is bilocular. The fruit is a samara, that is, an achene with a broad membranous wing (Fig. 196 *B*). The leaves are alternate, and always oblique. The annual shoots have no terminal bud, and so they form a sympodium. Two species of Elm are indigenous in England. *Ulmus campestris*, the common Elm, and *Ulmus montana*, the Wych or Mountain Elm: the former has rather slender branches, leaves with distinct petioles and serrate margins, somewhat narrow at the base, and a seed which is above the centre of the samara; the latter has thick horizontally spreading branches, leaves with very short petioles and doubly serrate margins, broad at the base, and a seed which is central in the samara. *Celtis australis*, from Southern Europe, and *C. occidentalis*, from North America, are often cultivated as ornamental trees; their flowers are polygamous, and they are placed singly or several together in the axils of the oblique acuminate leaves: the ovary is unilocular: the fruit is a drupe.

Order 5. PLATANEÆ. The diclinous flowers are arranged in glomerules borne laterally on pendulous branches. In the male glomerules a number of stamens are present together with scales which probably represent the several perianths: in the female glomerules there are similar scales among which are the unilocular ovaries, each containing a single suspended orthotropous ovule. They are trees destitute of latex, having scattered leaves and persistent sheathing stipules.

Platanus occidentalis, from North America, with three-lobed leaves, and *P. orientalis*, from the East, with usually five-lobed leaves, which are often cuneiform at the base, are frequently cultivated (especially the former). The smooth bark, which is shed in flakes, is very remarkable. The Plane may be at once distinguished from the Maples, which resemble it a good deal in the form of the leaf, by the scattered arrangement of the leaves.

Order 6. CERATOPHYLLEÆ. Submerged water-weeds of doubtful affinity, with whorled, sessile leaves dichotomously divided and subdivided; in the axils of some of these the diclinous monœcious flowers occur. The male flowers consist of from 6–12 perianth-leaves and about as many stamens; the female flowers have a similar perianth and a unilocular ovary with a single suspended orthotropous ovule.

Ceratophyllum demersum and *submersum* occur submerged in ponds and ditches.

Cohort 3. **Amentales.** The flowers, which are always diclinous and generally monœcious, are arranged in catkins (amenta). The perianth, when it is present, consists of five, four (*i.e.*, twice two), or six (*i.e.*, twice three) segments; the stamens are generally superposed on the segments of the perianth. The ovary is usually inferior, di- or tri-merous, with numerous ovules. The fruit (with the exception of Order 4, the Salicineæ) becomes by abortion one-seeded, and is indehiscent: the seed has no endosperm. The flowers are furnished with bracts which often form investments for the fruit: their arrangement in the first three families is as follows: in the axil of a primary scaly bract (the primary bracts being arranged spirally in the amentum) is a flower (*b*) with two bracteoles α and β, in the axil of each of which is another flower with two more bracteoles α' and β' (Fig. 197). They are trees and shrubs.

Order 1. BETULACEÆ. The flowers are monœcious, but in different catkins. The female flowers have no perianth: the ovary is bilocular, with two ovules: the fruit is one-seeded, indehiscent, without any investment: the primary bract is coherent with the two or four bracteoles (the bracteoles α' are always absent) to form a three or five-lobed scale, which does not adhere to the fruit.

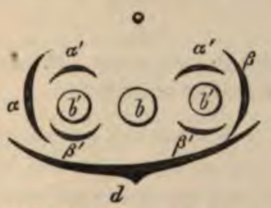


FIG. 197.—Diagram of a group of flowers in a typical amentaceous plant; *d* primary bract; *b* the median flower, with the secondary bracts (bracteoles), α and β; b' b'' the two lateral flowers, with the tertiary bracts, α' and β'.

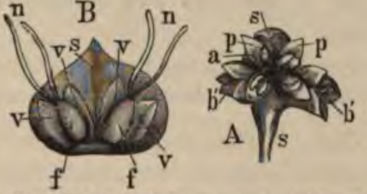


FIG. 198.—*A* Scale from a male catkin of *Alnus incana*: the axillary branch adheres to the scale (*s*), it bears four bracteoles and three flowers: two of the flowers are seen laterally (b' b'), the median one from above; *p* perianth; *a* stamens. *B* Scale (*s*) of a female catkin of the same plant: its axillary branch bears two lateral branches, each of which bears two bracteoles (*v v*) and one flower; *f* the ovary; *n* the stigmas (magnified and diagrammatic).

Alnus, the Alder. In the male amenta three flowers with four bracteoles occur in the axil of the primary bract, each flower having a perianth of four segments and four unbranched stamens. In the female amenta the median flower is absent; the four bracteoles coalesce with the primary bract (Fig. 198 *B v s*) to form a five-lobed woody scale which persists after the fall of the fruit which is not winged. The male catkins are borne terminally, and the female laterally on the highest lateral branch, on the shoots of the previous year; they are not enclosed by bud-scales during the winter, and blossoming takes place before the opening of the leaves. The leaves have usually a $\frac{1}{3}$ arrangement; in *A. incana*, the white Alder, the leaves are acuminate and gray on the under surface; in *A. glutinosa*, the black or common Alder, they are obovate or even emarginate and green on both surfaces. In *Alnus viridis*, the mountain Alder, the male catkins only are destitute of bud-scales in the winter.

Betula, the Birch. In the catkins of both sexes the three flowers have only the bracteoles α and β. In the male flowers the perianth is usually incomplete, and there are only two stamens, the filaments of which are forked. In the female catkins, the two bracteoles cohere with the primary bract to form a three-lobed scale which falls off together with the winged fruit. The male catkins are borne terminally on the shoots of the previous year, and are not covered with bud-scales during the winter; the female catkins are borne terminally on lateral dwarf-shoots, which have only a few leaves, and they are enclosed by bud-scales during the winter; as a consequence, flowering takes place after the unfolding of the leaves. The shoots of successive years form sympodia, and the leaves are arranged spirally. *B. verrucosa* has white glands on the leaves and young shoots; *B. pubescens* has no glands, but the shoots are hairy; it is a northern form; *B. fruticosa* and *B. nana* are shrubs occurring in high latitudes; *B. alba* is the common Birch.

Order 2. MYRICACEÆ. Trees or shrubs; the flowers, which are diclinous and sometimes diœcious, are arranged in catkins; a perianth may be present or absent, when present it is scaly. The ovary is dimerous and unilocular, with one erect orthotropous ovule.

Myrica Gale, the Bog-Myrtle, is a shrub occurring on moors. *M. cerifera*, belonging to North America, secretes a quantity of wax on its fruits.

Order 3. CASUARINEÆ. Trees having somewhat the appearance of Horse-tails (Equisetum), with long channelled internodes and leaves forming a toothed sheath. The flowers are in unisexual catkins; the male flowers consist of a single stamen and two perianth leaves, the female of a unilocular ovary invested by two bracteoles, which, when ripe, are hard and woody; the whole female catkin then resembles a pine-cone.

Several species of Casuarina are indigenous in Australia.

Order 4. SALICINEÆ. The diœcious flowers are arranged in amenta, and they are borne in the axils of the bracts without any bracteoles. The perianth is represented by a disc or a scale. The ovary is dimerous and unilocular, and contains a number of parietal ovules. The dehiscence of the fruit is loculicidal; the seeds are furnished with a pencil of silky hairs at their bases. The catkins are developed at the ends of lateral dwarf-shoots which always bear scales or even a few foliage-leaves.

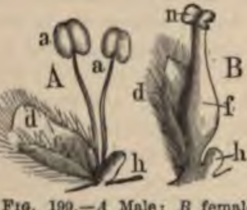


FIG. 199.—*A* Male; *B* female flower of Salix; *d* bract; *h* disc; *a* stamens; *f* ovary; *n* stigmas (enlarged).

Salix, the Willow, has entire bracts, one or more nectaries (glands) in each flower, and usually two stamens, entire shortly-stalked leaves, and its winter-buds are covered by a scale which is formed by the coalescence of two. The shoots, which grow throughout the summer, die down yearly. Some species, such as *S. alba*, *fragilis*, and *babylonica*, the Weeping Willow, have pendulous branches, and are arborescent; most of them are shrubby, and some, such as *S. reticulata*, *retusa*, and *herbacea* are small decumbent shrubs occurring in the Alps and in high latitudes. In *S. purpurea* and *incana* the two stamens are connate: *S. triandra* has three stamens. Most of the species grow on the banks of rivers; *S. aurita* and *capræa* in forests, and *S. repens* and others on moors.

Populus, the Poplar, has toothed or lobed bracts, a discoid perianth, and numerous (4–30) stamens; the leaves are often lobed and have long petioles; the winter-buds are enclosed by a number of scales; the shoots have a terminal bud. In the Section Leuce the young shoots are pubescent, and the buds are not viscid; the male flowers have usually only from 4–8 stamens, and the stigmas have 2–4 lobes: to this section belong *P. alba*, the White Poplar or Abele, with five-lobed leaves on the elongated shoots, which are woolly beneath; and *P. tremula*, the Aspen, with sinuate-serrate leaves, glabrous beneath, which are versatile on the long slender and compressed petiole, and which are therefore very readily set in motion by the wind. In the Section Aigeiros, the young shoots are glabrous and the buds viscid; the bracts are glabrous, and the number of stamens is usually from 15–30; the stigmas are entire or shortly lobed: to this section belong *P. nigra*, the Black Poplar, and a variety with erect branches, the Lombardy Poplar; of the latter, only male individuals are usually cultivated.

Cohort 4. **Euphorbiales.** Flowers usually diclinous; the perianth sometimes consists of calyx and corolla, sometimes it is simple, and occasionally it is absent: the ovary is usually trilocular, with one or two anatropous and generally suspended ovules in each loculus; the seed contains endosperm: the structure of the flowers is very various. The affinities of the group are not accurately known.

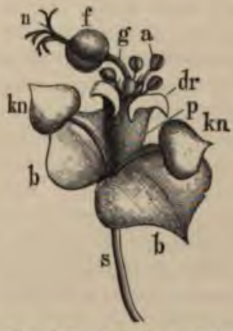


Fig. 200.—Part of an inflorescence of a Euphorbia: *b b* bracts in the axils of which are the flower buds (*kn*); *p* is the involucre of the cyathium; *dr* the glands; *a* the male flowers; *g* the pedicel of the female flower (*f*); *n* the stigmas (enlarged).

Order 1. EUPHORBIACEÆ. The fruit is usually dry and dehiscent, splitting septicidally into cocci. The micropyle of the solitary suspended ovule is directed outwards. They are plants of very various habit and floral structure, and they mostly contain milky juice.

The genus Euphorbia has cymose umbels or dichasia, the branches of which terminate in what were formerly regarded as hermaphrodite flowers, but are really inflorescences, each one being termed a *cyathium*. The cyathium consists of a tubular involucre (Fig.

200 *p*), between the five lobes of which glandular appendages, often of a semilunar form, are situated (Fig. 200 *dr*). Within this involucre are numerous male flowers in five groups, each of which consists of a single stamen (Fig. 200 *a*) and is terminal on a long pedicel, and one female flower (Fig. 200 *g*), consisting of a trilocular ovary (Fig. 200 *f*), at the base of which an indication of a perianth may in some cases be detected. That the cyathium is an inflorescence and not a single flower is most clearly visible in some foreign genera (Monotaxis), in which a perianth is distinctly developed round each stamen. There is a single ovule in each loculus of the trilocular ovary: the seed has a peculiar appendage termed a *caruncle*.

In Mercurialis the inflorescence is racemose: the male flowers have a three-leaved perianth and numerous stamens; the female flowers have a similar perianth and a bilocular ovary. The juice is not milky.

Ricinus bears its monœcious flowers in a compound inflorescence, in which the male flowers are placed below and the female flowers above. The perianth is simple and five-lobed, the stamens numerous and much branched (Fig. 142).

Of Euphorbia, the Spurge, a number of species are annual herbs, as *E. Peplus* and *helioscopia* (the common Sun Spurge) occurring in gardens and by roadsides; some South European forms are small shrubs, as *E. dendroides* and *fruticosa*. In Africa and the Canary Islands the genus is represented by species which much resemble Cacteæ in appearance; their stems are thick and cylindrical or angular or sometimes spherical, producing small leaves which usually soon fall off. *Mercurialis annua* and *perennis* (Dog's Mercury) are weeds; the first common in cultivated ground, the second in woods; their flowers are diœcious. *Ricinus communis* (the Castor-oil plant) is a native of Africa, now frequently cultivated. Some species of Phyllanthus have phylloid branches which bear their small flowers in the axils of minute bristle-like leaves situated in indentations at the edge of the phylloclade. *Manihot utilissima*, a South American plant, yields the starchy meal known in commerce as *tapioca*. From *Siphonia elastica*, a species growing in Central America, most of the caoutchouc is obtained.

Order 2. BUXINEÆ. The micropyle of the suspended ovule is directed inwards. Flowers monœcious, in glomerules, in which the terminal flower is usually female and the lateral ones male. Male flowers with a simple 4-leaved perianth and four superposed stamens; the female with a trilocular ovary: two ovules in each loculus: fruit a capsule, with loculicidal dehiscence. For the most part shrubs devoid of milky juice.

Buxus sempervirens, the Box, is an evergreen shrub of Southern Europe; the wood is valuable.

Cohort 5. **Daphnales.** Flowers hermaphrodite or unisexual, actinomorphic, 4 or 5-merous: perianth simple or biseriate; in the latter case the corolla is usually suppressed: stamens typically in two whorls, perigynous: ovary monomerous, with usually a single anatropous ovule inserted on the floor of a hollow receptacle: embryo straight.

Order 1. THYMELÆACEÆ. Flowers hermaphrodite; calyx and receptacle petaloid, with a 4-lobed limb; corolla suppressed, or represented by small scales: the four stamens opposite to the sepals are inserted higher on the tube of the calyx than the four which are opposite to the petals (Fig. 201): ovule suspended; fruit a berry: seeds without endosperm.

Daphne Mezereon is common in woods; the usually 3-flowered inflorescences are borne in the axils of the foliage leaves of the previous year, and they bloom before the development of the leaves of the same year.

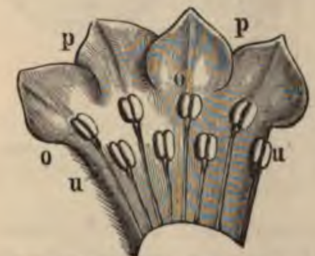


FIG. 201.—Calyx of the flower of *Daphne Mezereon* laid open (× 5): *o* the four superior; *u* the four inferior stamens, adnate to the calyx.

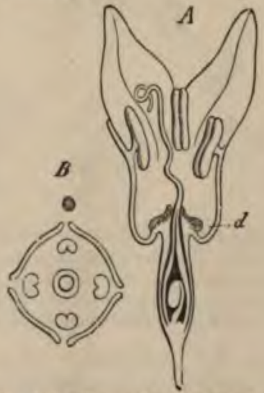


FIG. 202.—Hermaphrodite flower of *Elæagnus fusca*. *A* In longitudinal section. *B* Floral diagram (the calyx is erroneously placed diagonally, instead of medio-laterally); d disc (enlarged.) (After Sachs.)

Order 2. ELÆAGNACEÆ. Flowers diclinous or polygamous, 4 or 2-merous; the corolla is suppressed: the stamens opposite to the sepals are sometimes wanting (Fig. 202 *B*); a disc (Fig. 202 *A*, *d*) usually closes the receptacle: fruit an achene, surrounded by the receptacle or by the whole perianth: ovule basal: seeds with small endosperm: the leaves are covered, especially on the under surface, with scaly hairs.

Hippophaë rhamnoides, the Sea Buckthorn, is a shrub which is sometimes common on the banks of streams; the smaller branches mostly terminate in a thorn; the flowers are diœcious and dimerous; when the fruit is ripe the calyx is of an orange colour. Elæagnus has tetramerous polygamous flowers (Fig. 202); it is commonly cultivated.

Order 3. PROTEACEÆ. Affinities doubtful. Flowers hermaphrodite; the very short stamens are superposed on the four segments of the simple perianth, and are adnate to them (Fig. 203 *B*): when the flower opens, the tube of the perianth often becomes still more deeply cleft: the ovary is usually borne upon a prolongation of the axis (Fig. 203 *C*, *gp*): ovules one or more, ascending: seeds without endosperm.

Protea, Grevillea, Manglesia, and others occur mostly in South Africa and in Australia.

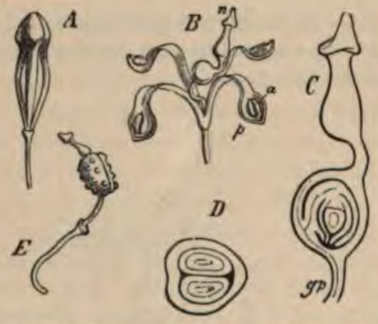


FIG. 203.—Flower of *Manglesia glabrata*. *A* Before opening. *B* Open; *p* segment of the perianth: *a* anther; *n* stigma. *C* Ovary below, in longitudinal section; *gp* gynophore. *D* Transverse section of the ovary. *E* Ripe fruit. (After Sachs.)

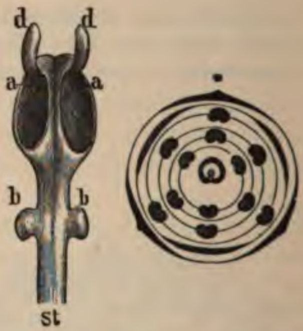


FIG. 204.—Stamen of Laurus. *A* Anthers opened, *a a*; *d d* the valves; *b b* glandular appendages. Diagram of Cinnamomum.

Order 4. LAURINEÆ. Flowers hermaphrodite or polygamous, cyclic, usually trimerous (dimerous in Laurus); perianth simple, sepaloid, in two whorls; stamens 12, in four whorls; the anthers open by 2 or 4 valves, sometimes introrse, sometimes extrorse; the filaments have glandular appendages (Fig. 204 *bb*). Ovary trimerous (drawn as monomerous in Fig. 204), unilocular with one suspended ovule, two of the three carpels being abortive. Fruit a berry or a drupe. Seed devoid of endosperm.

These are usually evergreen shrubs with coriaceous leaves; a few, as Cassytha, are parasites resembling the Dodder in habit.

Order 5. MYRISTICEÆ. Flowers diclinous, cyclic; perianth simple, gamophyllous, 3-lobed. Stamens 3–18 coherent into one bundle. Ovary monomerous, with one basal ovule: fruit a fleshy two-valved capsule: seed with endosperm.

Myristica moschata, the Nutmeg, is a native of the Moluccas. The seed is invested by an arillus, an integument which is developed after fertilisation; it has a netted or laciniate appearance (Fig. 205 *a*); it is known in commerce as Mace. Seed large, with much endosperm, the surface of which is corrugated; the innermost layer of the brown testa closely follows all the windings, and this gives the endosperm a marbled appearance.

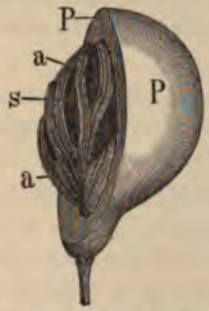


FIG. 205.—Fruit of the Nutmeg-tree, *Myristica moschata*. *P* Pericarp, half of it removed; *s* the seed; *a* arillus (nat. size).

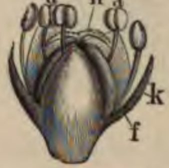


FIG. 206.—Flower of Chenopodium (enlarged): *k* perianth; *a* stamens; *f* ovary; *n* stigma.

Cohort 6. **Chenopodiales.** Flowers usually hermaphrodite; perianth sepaloid or petaloid; ovary monomerous or polymerous; ovule usually solitary; embryo coiled or curved.

Order 1. CHENOPODIACEÆ. Flowers small, united to form a dense inflorescence: the bracteoles are usually suppressed. Stamens superposed on the usually 5-leaved sepaloid perianth (Fig. 206). Ovary usually dimerous and unilocular, with a single basal ovule. Stipules wanting.

Chenopodium album, the Goose-foot, and *Blitum* (*Chenopodium*) *Bonus Henricus*, the All-good, are common weeds on garden ground and waste land. *Spinacia oleracea* is Spinach, cultivated as a vegetable. *Beta vulgaris* is cultivated under the var. *Cicla* (Mangold). *B. altissima* is the species used in the manufacture of sugar, and *B. rubra* is the red Beetroot. *Salsola*, the Salt-wort, and its allies, with fleshy stems and leaves, are conspicuous in the vegetation of the sea-shore.

Order 2. AMARANTACEÆ. The flowers have the same structure as those of the preceding family: they have usually bracteoles which are frequently petaloid: ovary unilocular, probably polymerous: ovule solitary and basal, but in some cases the ovules are numerous. Stipules absent. The flowers usually form dense inflorescences.

Species of Amarantus and Celosia (Cock's comb), the latter having a monstrous floral axis, are well known as ornamental plants.

Order 3. PHYTOLACCACEÆ. The flowers have a simple, generally 5-leaved perianth which is often petaloid, and two whorls of stamens; the number of the stamens is in many cases doubled (Fig. 207): the number of carpels varies very much; when the ovary is polymerous it is multilocular, each loculus containing a single ascending ovule. Stipules occasionally present.

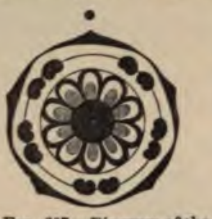


FIG. 207.—Diagram of the flower of *Phytolacca decandra*.

Phytolacca decandra, a native of North America, is used as a colouring-matter in the manufacture of wine and in other processes.

Order 4. NYCTAGINEÆ. Perianth simple, petaloid, gamophyllous, 5-leaved; stamens in greater or smaller numbers; ovary monomerous, unilocular, with one basal anatropous ovule; the terminal flowers are surrounded by an epicalyx, but not the lateral ones.

Mirabilis Jalapa, the Marvel of Peru, is an ornamental plant from America; the roots are often substituted for those of the true Jalap.

Order 5. POLYGONEÆ. The flowers have a simple 4, 5, or 6-leaved perianth which may be either sepaloid or petaloid, and usually the same number of superposed stamens; but occasionally the stamens are more numerous or some of them are suppressed. Ovary usually trimerous, unilocular, with a single basal orthotropous ovule; the fruit is frequently more or less enveloped by the persistent perianth. The leaves have well-developed sheaths (Fig. 208 *A v*) and connate stipules forming an *ochrea* (Fig. 208 *o*) which embraces the stem for some distance above the leaf-sheath.

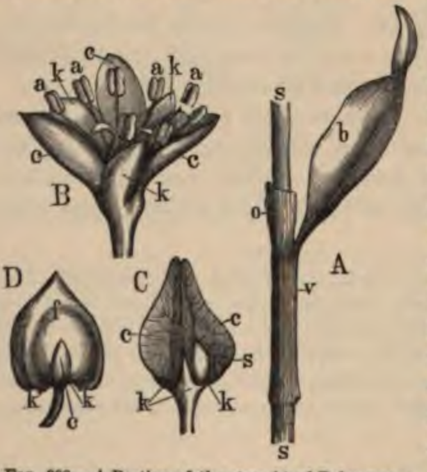


FIG. 208.—*A* Portion of the stem (*s*) of Polygonum, with a leaf (*b*), its sheath (*v*), and the ochrea (*o*) (nat. size). *B* Flower of Rheum; *k* external, *c* internal perianth-whorl; *a* the stamens. *C* Fruit of Rumex, enclosed by the inner whorl of the perianth; *s* base of one of the perianth leaves; *k* external perianth leaves, *D* Fruit of Rheum (*f*); *k* outer, *c* inner perianth-whorl (enlarged).

Rheum, the Rhubarb, has six (three internal and three external) perianth leaves and two whorls of stamens, the outer containing six, and the inner three; *Rheum undulatum* and other species are cultivated. Rumex, the Dock, has flowers of similar structure, but the inner whorl of stamens is absent; the triquetrous fruits are completely enveloped by the inner whorl of perianth leaves (Fig. 208 *c*); the leaves contain a large quantity of oxalic acid. Polygonum has usually five petaloid perianth leaves and a varying number of stamens (5–8); *P. Fagopyrum*, the Buckwheat, is cultivated for the sake of its mealy seeds.

Cohort 7. **Nepenthales.** Flowers diœcious; perianth simple; stamens monadelphous; ovary 3–4-locular; ovules indefinite.

Order 1. NEPENTHEÆ. The lamina of the leaf of Nepenthes has a pitcher-like form, and is termed an *ascidium;* it is an adaptation for the purpose of capturing insects.

SERIES II. EPIGYNÆ.

Ovary inferior.

Cohort 1. **Quernales.** Flowers diclinous: ovary 1–6-locular; ovule 1, basal or suspended: seeds without endosperm.

Order 1. JUGLANDEÆ. Flowers monœcious, the two kinds of flowers being contained in distinct catkins. Each bract bears in its axil a single flower with two bracteoles. The ovary is dimerous, and encloses a single erect orthotropous ovule. The male flowers are usually borne on the bract; they may or may not have a perianth, and the stamens are indefinite (Fig. 209 *A*). The fruit is drupaceous; the leaves are pinnate, and, like the flowers, they are aromatic.

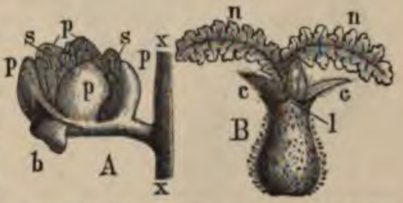


FIG. 209.—*A* Scale of the male catkin of *Juglans nigra* bearing a flower; *p* perianth and bracteoles; *s* stamens; *x* axis of the catkin. *B* Female flower of the same plant; *l* bracteoles; *c* perianth; *n* stigmas (magnified).

In Juglans the male catkins are borne on the apices of the leafless shoots of the previous year, and the few-flowered female catkins on the apices of the leafy shoots of the same year. The bracteoles of the female flowers (Fig. 209 *l*) grow up around the ovary. The succulent mesocarp is thin, and ruptures irregularly; the hard endocarp opens on germination along the line of junction of the two carpels, and then the incurved margins of the carpels are seen as an incomplete longitudinal septum projecting between the two cotyledons of the embryo which is closely invested by the endocarp. *J. regia*, the Walnut Tree, is a native of Southern Europe; in North America, *J. cinerea* and *nigra* occur; also various species of Carya, the Hickory, remarkable for its very hard wood.

Order 2. Corylaceæ. Flowers monœcious, in male and female catkins. The male flowers have no perianth; that of the female flower is rudimentary. The ovary is bilocular; one loculus is sterile, the other contains two suspended anatropous ovules: the fruit is one-seeded and indehiscent (a nut). Two flowers are borne in the axil of the primary bract of the female catkin, the median flower being absent. Each fruit is surrounded by a leafy investment (cupule) formed by the three bracteoles ($\alpha\ \alpha_1\ \beta_1$ and $\beta\ \alpha_1\ \beta_1$ respectively, Fig. 197) of each side. In the male catkin the median flower only is developed; the filaments of the stamens are deeply forked.

In Corylus, the Hazel, the female catkin resembles a bud, since the external sterile bracts have the same structure as the bud-scales (Fig. 210 *B*); the red stigmas project at the top; the investment of the fruit is irregularly cut; a small projection is formed on the fruit, the nut, by the remains of the perianth. Each primary bract of the male amentum bears two bracteoles α and β, and four forked (so apparently eight) stamens (Fig. 210 *A*). Both kinds of amenta are placed in the axils of the leaves of the previous year, and are not enclosed by scales during the winter; hence flowering takes place before the unfolding of the leaves. Leaves distichous. *C. Avellana* is the common Hazel; *C. tubulosa*, with red leaves, the Copper Hazel, is cultivated as an ornamental shrub.

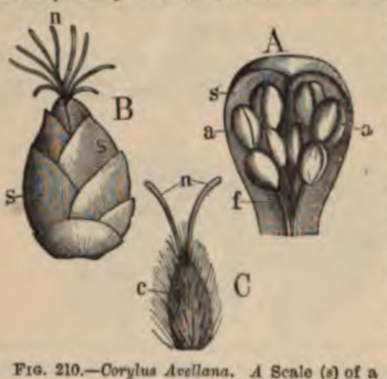


Fig. 210.—*Corylus Avellana*. *A* Scale (*s*) of a male catkin, with the stamens (*f*), and anthers (*a*). *B* Female catkin: the lower scales (*s*) have no flowers; the stigmas (*n*) project above. *C* A single female flower surrounded by the investment (bracteoles) (*c*), with two stigmas (*n*) (mag. and diag.).

In Carpinus, the Hornbeam, the fruit has a three-lobed investment; the fruit is ribbed and is surmounted by the perianth. The primary bract of the male catkin bears 4–10 deeply forked stamens; there are no bracteoles. The catkins of both kinds are borne at the apex of short leafy shoots of the same year, hence flowering takes place after the unfolding of the leaves. Leaves distichous. The annual shoots form sympodia. *C. Betulus* has an irregular stem and serrate leaves which are folded along the lateral veins. In Ostrya (Southern Europe) the investment of the fruit is an open tube.

Order 3. Cupuliferæ. Flowers monœcious, with a perianth of five or six segments. Ovary trilocular, with two ovules in each loculus; ovules anatropous, ascending or suspended: the fruit is one-seeded and indehiscent (a nut); it is invested by a cupule formed probably by the connate bracteoles $a_1\ \beta_1\ a_1\ \beta_1$ (Fig. 197), and having its surface covered with scales, prickles, etc. The filaments are not forked.

In Quercus, the Oak, the male catkins are loose; each bract bears a single flower in its axil without bracteoles: the perianth is 5–7 lobed, and the stamens from 5–10 or indefinite (Fig. 211 *a*). There is a single flower, the median one, in the axil of each bract of the female catkin; thus the cupule invests only a single fruit, forming the so-called cup at its base. The leaves are developed in $\frac{2}{5}$ order near the apices of the annual shoots; the annual shoots are always apical. The male catkins are borne in the axils of the uppermost bud-scales (pairs of stipules) on both long and dwarf shoots of the same year, the female catkins in the axils of the foliage-leaves of the apical shoots: flowering takes place shortly after the unfolding of the leaves. The ovules are ascending. The cotyledons remain enclosed in the testa during germination. *Quercus Robur* is the English species, of which there are two varieties, *Quercus pedunculata* and *Quercus sessiliflora:* the former has elongated female catkins, so that the fruits are widely separated from each other, and its pinnately lobed leaves are shortly stalked and cordate at the base: the latter has compact female catkins, so that the fruits form a cluster, and its leaves have longer petioles, and are narrowed at the base. *Quercus Suber* is the Cork-Oak of Southern Europe. There are also several North American species.

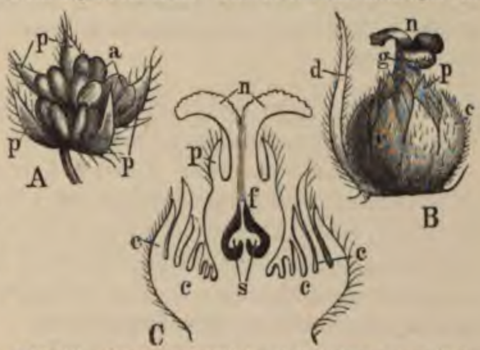


FIG. 211.—*Quercus pedunculata.* *A* Male flower magnified; *p* perianth; *a* stamens. *B* Female flower magnified; *d* bract; *c* cupule; *p* the superior perianth; *g* the style; *n* the stigma. *C* The same still more magnified, in longitudinal section; *f* ovary; *s* ovules.

In Fagus, the Beech, the catkins of both kinds have the appearance of stalked capitula. The flowers of the male catkin are closely packed; they have a perianth of 4–7 segments and 8–12 stamens. The female catkin consists of two flowers only, which are invested by a single cupule and by four delicate leaflets. The cupule is covered with hard bristles, and when ripe splits into four valves to allow the two triquetrous fruits to escape; each fruit bears at its apex a brush-like remnant of the perianth. The ovules are suspended. The female inflorescences are borne on erect axes in the axils of the leaves of the apical shoot of the same year, the male on pendulous axes springing from the axils of the lower leaves of the shoots. Leaves distichous, approaching each other on the under surfaces of the shoots, their axillary buds approaching each other on the upper surface: the winter buds are elongated and pointed. The cotyledons escape from the seed on germination. *Fagus sylvatica* is the common Beech: a variety with red leaves, the Copper Beech, is very generally cultivated.

In Castanea, the edible or Spanish Chestnut, some of the catkins consist at their lower part of female flowers and at their upper of male flowers, whilst others have only male flowers. In the axil of each bract there are usually either seven male or three female flowers; the latter are invested by the bracteoles α and β, and by a cupule formed by the other four bracteoles; the cupule, which is covered with prickles, completely encloses the fruit until it is ripe, when it splits into four valves. Both kinds of catkins are formed in the axils of leaves of shoots of the same year, the mixed catkins being nearer to the apex than the male ones. The ovules are suspended. The leaves are arranged spirally on vigorous shoots; they are distichous on the less vigorous lateral shoots. *C. vulgaris*, from Southern Europe, is cultivated in parks; it has undivided toothed leaves.

Cohort 2. **Asarales.** Flowers hermaphrodite or unisexual: ovary multilocular: ovules numerous.

Order 1. ARISTOLOCHIEÆ. Flowers hermaphrodite: perianth of three connate petaloid segments forming a three-lobed tube: stamens 6 or 12: ovary usually 6-locular, with numerous ovules in two longitudinal rows along the inner angles of the loculi. The minute embryo is enclosed in the copious endosperm. They are herbs or shrubs, often climbing, with large leaves.

In *Asarum europæum* (Asarabacca) the three lobes of the perianth are equal; the twelve stamens are free, and the connective is produced (Fig. 212). The annual shoots of the creeping stem bear four cataphyllary leaves, two large petiolate reniform foliage-leaves, and a terminal flower. The lateral branches spring from the axils of the uppermost foliage-leaf and of the scales. In Aristolochia (see Fig. 154 *p*) the limb of the perianth is obliquely lipped; the six anthers are sessile and adnate to the short style. *A. Sipho* is a climber frequently cultivated; *A. Clematitis* occurs on ruins, etc.; the flowers of the latter occur usually several together in the axils of the leaves, and those of the former in pairs, one above the other, together with a branch in the axils of the leaves of the shoot of the previous year.

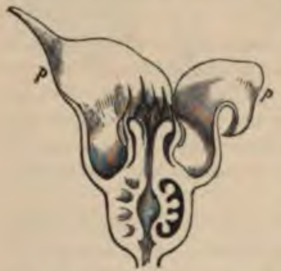


FIG. 212.—*Asarum europæum.* Longitudinal section of the flower (mag.); *p* perianth. (After Sachs.)

Order 2. CYTINACEÆ. Parasites devoid of chlorophyll and without foliage-leaves, with a usually deformed vegetative body, and either solitary flowers of remarkable size or small flowers in a compact inflorescence. Flowers hermaphrodite or unisexual: perianth campanulate: ovary unilocular: ovules very numerous; embryo rudimentary: seed with or without endosperm.

Sub-order 1. CYTINEÆ. *Cytinus Hypocistis* is parasitic on the roots of Cistus in Southern Europe; other species occur in America and South Africa.

Sub-order 2. HYDNOREÆ. Hydnora and others are parasitic on the roots of Euphorbiæ in America and in South Africa.

Sub-order 3. RAFFLESIACEÆ. *Rafflesia Arnoldi* is conspicuous for the enormous size of its flower; it is parasitic on the roots of Ampelideæ in the East India Islands.

Cohort 3. **Santalales.** Parasitic plants: leaves, when present, entire: stamens equal in number to the leaves of the perianth and superposed upon them; ovary unilocular; ovules devoid of integument.

Order 1. SANTALACEÆ. Parasites provided with chlorophyll: flowers generally hermaphrodite; ovules 1–4, suspended upon a free central placenta: perianth 3–5-lobed; fruit a nut or drupe.

Thesium linophyllum, the Bastard Toad-flax, is an indigenous plant which is parasitic on the roots of other plants. The leaves are narrow and linear. The bracts of the flowers, which are disposed in racemes, are usually placed high up on the pedicels, close under the flowers, and in most of the species constitute with the bracteoles a three-leaved epicalyx. The stamens are filiform, inserted at the base of the lobes of the perianth. The perianth is persistent, remaining curled up at the apex of the indehiscent fruit (Fig. 213 *B*). *Santalum album*, an East Indian tree, yields Sandal-wood.

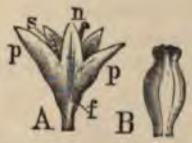


FIG. 213.—*A* Flower; *B* fruit of *Thesium montanum*: *f* ovary; *p* perianth; *s* stamens; *n* stigma (enlarged).

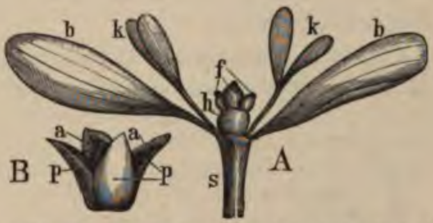


FIG. 214.—*A* Terminal shoot of a female plant of the Mistletoe, *Viscum album*: *s* stem; *b b* leaves; *k k* axillary buds; *f* three female flowers with the fruit set. *B* Male flower (mag.); *p* perianth; *a* anthers adherent to the leaves of the perianth.

Order 2. LORANTHACEÆ. Parasites provided with chlorophyll: flowers diclinous or hermaphrodite; ovule erect, adhering to the wall of the ovary: perianth of 4, 6, or 8 leaves; fruit a berry.

Viscum album, the Mistletoe, is parasitic on various trees, forming conspicuous evergreen bunches. The stem bears a pair of opposite leaves (Fig. 214 *b b*), from the axils of which new branches spring, each bearing a pair of cataphyllary leaves and then a pair of foliage-leaves, while the main axis ceases to grow, or produces a terminal inflorescence, consisting of three flowers (Fig. 214 *h f*) branches or inflorescences may also spring from the axils of the cataphyllary leaves. The flowers are diœcious. The fruit is a one-seeded berry with a viscid pericarp, by means of which the seeds become attached to trees, and thus effect the distribution of the plant. The male flowers have multilocular sessile anthers which are inserted (Fig. 214 *B a*) upon the leaves of the perianth. *Loranthus europæus* occurs upon Oaks in Eastern Europe.

Order 3. BALANOPHOREÆ. Parasites devoid of chlorophyll and without foliage-leaves, with a deformed vegetative body. Flowers diœcious or monœcious, in many-flowered inflorescences. The female flowers usually consist of a one-seeded ovary: the ovule is suspended, and it adheres closely to the ovary. The embryo is very small.

Balanophora, Lophophytum, and others are Brazilian genera; others inhabit tropical Africa; *Cynomorium coccineum* is found in the Mediterranean region.

SUB-CLASS II. GAMOPETALÆ.

Flowers usually hermaphrodite: perianth differentiated into calyx and corolla; calyx usually gamosepalous; corolla generally gamopetalous, in some cases it is suppressed.

SERIES I. HYPOGYNÆ.

Ovary superior (except in Vaccinieæ): stamens epipetalous, or free and hypogynous.

Cohort 1. **Lamiales.** Flower pentamerous, usually zygomorphic with median symmetry: corolla usually bilabiate, the two posterior petals being connate and forming a frequently helmet-shaped (*galeate*) projecting upper lip, the anterior petal, with the two lateral petals, forming the under lip: stamens epipetalous: the posterior stamen is usually abortive or appears as a staminode; the two lateral stamens are generally shorter than the two anterior ones, so that the flower is didynamous; the two median carpels

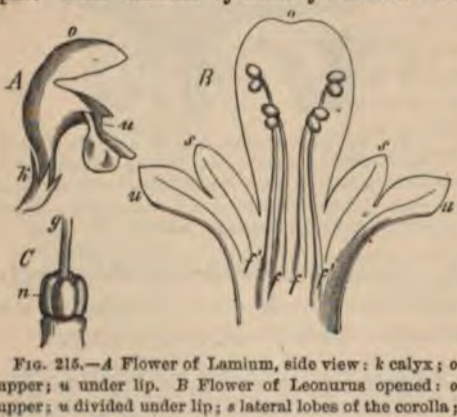


FIG. 215.—*A* Flower of Lamium, side view: *k* calyx; *o* upper; *u* under lip. *B* Flower of Leonurus opened: *o* upper; *u* divided under lip; *s* lateral lobes of the corolla; *f f* shoot; *f′ f′* long stamens (mag.). *C* Ovary; *n* achænia; *g* style (mag.).

form a usually bilocular ovary which is sometimes subdivided into four loculi: leaves scattered or opposite decussate, exstipulate: the leafy shoots have no terminal flower: the formula is generally $\downarrow K (5) (C(5) A5) G^{(\underline{2})}$.

Order 1. LABIATÆ. Stamens four, didynamous (Fig. 215 *B*); rarely, as in Salvia and its allies, only the two anterior stamens are developed: ovary subdivided into four chambers, as in the Boragineæ, which part as the seed ripens into four achænia (Fig. 215 *C*): style lateral: the ovule in each loculus is solitary and erect: seed without endosperm. Herbs with decussate leaves and quadrangular stem. The flowers are disposed apparently in whorls round the stem, but the inflorescence is in fact made up of compound cymes or dichasia, termed verticillasters, developed in the axil of each of the two opposite leaves.

Tribe 1. *Ocymoideæ*. Stamens 4, descending.

Ocymum Basilicum, the Sweet Basil, from India, and Lavandula, the Lavender from Southern Europe, are cultivated as potherbs.

Tribe 2. *Menthoideæ*. Stamens 4, equal, ascending, divergent: corolla almost regular, 4- or 5-lobed.

Many species of Mentha, Mint, are common. Several species of Coleus, and *Pogostemon Patchouli*, yielding oil of Patchouli, are cultivated. Lycopus has only 2 stamens, the two posterior ones being abortive.

Tribe 3. *Satureineæ*. Stamens 4, with broad connective, divergent, ascending.

Origanum vulgare is the Wild Marjoram; the Sweet Marjoram which is cultivated is an exotic species. *Thymus Serpyllum* is the Wild Thyme; the Garden Thyme is *T. vulgaris*, from Southern Europe. *Satureia hortensis* (exotic) is the Summer Savory. Various species of Calamintha (stamens not divergent) are common, as also *Clinopodium vulgare* (or *C. Clinopodium*), the Wild Basil.

Tribe 4. *Melissineæ*. Stamens 4, with narrow connective, divergent.

Melissa officinalis, the Balm, and Hyssopus, the Hyssop, are cultivated as potherbs.

Tribe 5. *Monardeæ*. Stamens 2, ascending: one cell of each anther is either wanting or it is widely separated from the other.

Salvia verbenacea, the Wild Sage, is common. *Rosmarinus officinalis*, the common Rosemary, is exotic.

Tribe 6. *Nepeteæ*. Stamens 4, ascending; the posterior two are the longer.

Nepeta Cataria, the Catmint, occurs in hedges; and *Glechoma hederacea*, the Ground Ivy, is very common.

Tribe 7. *Stachydeæ*. Stamens 4, ascending; the anterior two are the longer: upper lip of corolla usually arched (ringent).

Lamium album, the Dead-Nettle, and *purpureum* are very common. Various species of Galeopsis, Stachys, Marrubium (Horehound), Ballota, Melittis, and Leonurus, are found in England.

Tribe 8. *Scutellariæ.* Stamens 4, ascending: calyx closed when the fruit is ripe.

In the genus Scutellaria, the anthers of the anterior pair of stamens are unilocular; *S. galericulata*, the Common Skullcap, and *S. minor*, the Lesser Skullcap, are common. In the genus Prunella each filament has a small tooth below the anthers: *P. vulgaris* is common.

Tribe 9. *Ajugoideæ.* Stamens 4, ascending; the posterior two are the shorter: upper lip of corolla very short.

Ajuga reptans, the Creeping Bugle, and *Teucrium Scorodonia*, the Wood Germander, are common.

Order 2. VERBENACEÆ. Stamens four, didynamous, or two: ovary 1 or 2-locular, with two ovules in each loculus, or spuriously 2 or 4-locular in consequence of the presence of false dissepiments, with one ovule in each loculus: endosperm small or absent: the fruit separates into 2–4 segments (achænia): style terminal: leaves usually opposite.

Verbena officinalis, the Vervain, is common on waste ground and roadsides: *V. Aubletia* is a common garden plant. *Tectona grandis*, the Teak-tree of the East Indies, has a hard wood used in ship-building.

Order 3. GLOBULARIEÆ. Stamens four, didynamous: ovary unilocular, with one suspended ovule: style lateral: seed with endosperm: leaves scattered, inflorescence capitulate.

Globularia vulgaris and *cordifolia* with radical leaves occur here and there in dry places on the Continent.

Order 4. PLANTAGINEÆ. Flowers actinomorphic and apparently tetramerous, but the true interpretation of them is deduced from those of Veronica: the posterior sepal is suppressed, as also the posterior stamen; the two posterior petals cohere to form an upper lip which is quite similar to one of the lobes of the three-lobed lower lip; stamens four, the two anterior not being suppressed: ovary unilocular or spuriously 2–4-locular: ovules solitary and basal, or numerous: fruit a capsule with transverse dehiscence, or an achænium: seed with endosperm.

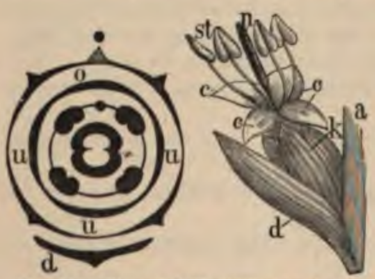


FIG. 216.—Flower of Plantago: *a* axis of the inflorescence (scape); *d* bract; *k* calyx; *c* corolla; *st* stamens; *n* stigma (mag.). In the diagram, *o* is the upper, and *u* the under lip.

Plantago lanceolata (Ribwort), *major*, *media*, the Plantains, are weeds universally distributed. The leaves form a rosette just above the root, and the long scapes spring from their axils bearing simple spikes (Fig. 216 *a*, *d*). In *P. Cynops*, *Psyllium*, and others, the main stem is elongated: the testa of the seed is mucilaginous. In *Litorella lacustris* the flowers are monœcious; it grows on the bottom of shallow waters: fruit 1-seeded, indehiscent.

Cohort 2. **Personales.** Flowers pentamerous, zygomorphic, with median symmetry: stamens epipetalous: the posterior stamen is usually abortive, or appears as a staminode: carpels 2, median: ovules usually indefinite.

Order 1. SCROPHULARINEÆ. Ovary bilocular, with numerous anatropous ovules borne on axile placentæ: seed with endosperm: stamens four, didynamous, often with a rudimentary fifth posterior stamen (Fig. 218 *B*, *st*); sometimes only the two lateral stamens are present; rarely all five are fertile: general floral formula as in Lamiales.

Sub-order 1. ANTIRRHINEÆ. The posterior petals, forming the upper lip of the corolla, are usually outside the others in the bud (cochlear æstivation).

In the genus Verbascum, the Mullein, the flower is imperfectly zygomorphic, the 5 stamens are unequal in length (2 long, 3 short): *V. Thapsus*, the Great Mullein, *V. Lychnitis*, the White Mullein, and *V. nigrum*, the Dark Mullein, occur on banks and waysides. Antirrhinum, the Snapdragon, has a projection on the lower lip of the corolla termed the palate; the corolla is gibbous at the base; stamens 4 (Fig. 218 *A B*): *A. majus*, the great Snapdragon, is a well-known garden plant. Linaria has a spurred corolla; stamens 4: *L. vulgaris*, the yellow Toad-Flax, is common in fields. In Gratiola the two anterior stamens are represented by staminodes. *Paulownia imperialis* is an ornamental flowering tree from Japan. Many species of Mimulus (Musk), Calceolaria, and Pentastemon, are cultivated.

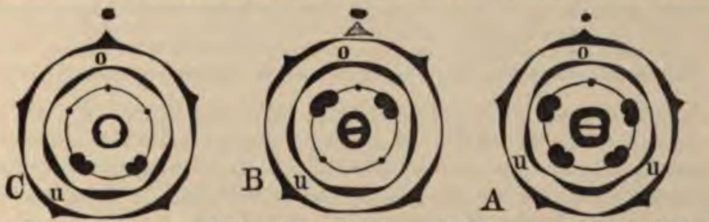


FIG. 217.—Floral diagrams, *A* Of most Scrophularineæ. *B* Of Veronica. *C* Of the Lentibularieæ; *o* upper; *u* under lip.

Sub-order 2. RHINANTHEÆ. Corolla with imbricate æstivation. Digitalis, the Foxglove, has an obliquely campanulate (digitaliform) corolla; stamens 4: *D. purpurea* is common in woods; the yellow *D. grandiflora* is cultivated. Scrophularia has a globular corolla; *S. nodosa* (Figwort) and *S. aquatica* are common. Veronica, the Speed-well, has only the 2 lateral stamens, and the two lobes of the upper lip of the (rotate) corolla are united; the posterior lobe of the calyx is suppressed (Figs. 218 *C*, 217 *B*): *V. Anagallis* and *V.*

Beccabunga are common in ditches, *V. arvensis*, *agrestis*, *serpyllifolia*, and others in pastures and fields.

Pedicularis has a 5-toothed calyx, and the upper lip of the corolla is galeate; Euphrasia, the Eyebright, has a 4-toothed calyx, the upper lip of the corolla has two spreading or reflexed lobes: Bartsia has a 4-toothed calyx, the upper lip of the ringent corolla is entire or only notched: Rhinanthus, the Rattle, has a 4-toothed inflated calyx: Melampyrum has a 4-toothed tubular calyx, and the capsule is few-seeded: all these plants possess chlorophyll, but they are more or less parasitic upon the roots of other plants. *Lathræa squamaria* does not possess chlorophyll; it is of a pale rose colour, with slightly bluish flowers; it is parasitic on the roots of trees, especially of the Hazel.

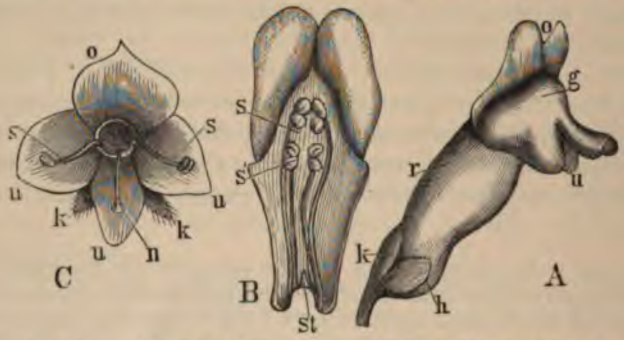


FIG. 218.—Flowers of Scrophularineæ. *A* Antirrhinum: *k* calyx; *r* tube of the corolla, gibbous at the base (*h*); *o* upper; *u* under lip of the corolla; *g* prominence of the under lip. *B* Upper lip of the same, seen from within: *s* the two longer anterior stamens; *s'* the short lateral ones; *st* rudimentary posterior one. *C* Flower of Veronica: *k* calyx; *u u u* the three lobes of the lower lip; *o* the lobed upper lip; *s s* the two lateral stamens; *n* stigma.

Order 2. BIGNONIACEÆ. Stamens generally four, didynamous: seeds usually winged, without endosperm. Woody plants or climbers.

Catalpa bignonioides is an ornamental tree from North America.

Order 3. ACANTHACEÆ. Stamens four, didynamous: ovules few on projecting placentæ: seed without endosperm. Herbs.

Acanthus mollis and other species from Southern Europe, are ornamental plants.

Order 4. GESNERACEÆ. Stamens usually four, didynamous, or sometimes two only: ovary unilocular, with numerous parietal ovules. Generally herbs with opposite leaves.

Columnea Schiedeana, Achimenes, Ligeria, and others are ornamental plants from tropical America.

Order 5. OROBANCHEÆ. Plants which are parasitic on the roots of other plants, destitute of chlorophyll, with scales instead of leaves, otherwise similar to the foregoing.

Orobanche rubens and *cruenta* (Broomrapes) on Leguminosæ, *lucorum* on Berberis, *Hederæ* on Ivy, *ramosa* on Hemp ; mostly of a brownish or whitish hue.

Order 6. LENTIBULARIEÆ. Only the two anterior stamens are developed (Fig. 217 *C*): ovules numerous on a free central placenta: seed without endosperm.

The numerous species of Utricularia are floating water-plants with finely divided leaves bearing bladder-like appendages which serve to catch small aquatic animals (Fig. 219). *Pinguicula vulgaris* and *alpina* (Butterworts) are small plants with rosettes of radical leaves growing in damp places.

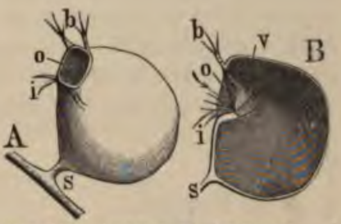


FIG 219.—Bladders of Utricularia. *A* Outside view: *s* pedicel; *o* entrance; *i* and *b* bristly appendages. *B* Section: *v* a valve opening inwards and preventing the exit of the imprisoned animal (mag.).

Cohort 3. **Polemoniales.** Flowers actinomorphic, or if zygomorphic, not so in the median plane: flowers pentamerous: stamens epipetalous: ovary of two, rarely five, carpels: leaves usually scattered and exstipulate: the inflorescence is often cymose, with a terminal flower: formula $K(5)\ (C(5)\ A5)\ G^{\underline{(2)}}$ to $(\underline{5})$.

Order 1. CONVOLVULACEÆ. Usually two median carpels forming a bilocular ovary, with 1–2 anatropous ovules in each loculus: the corolla has usually a contorted æstivation, twisted to the right: fruit a septifragal capsule or a berry: seed with endosperm. Commonly climbing plants with milky juice.

Convolvulus arvensis, the lesser Bindweed, and *Calystegia sepium*, the larger Bindweed, the former with small bracts, the latter with large bracts which invest the calyx, are common wild plants. *Batatas edulis* is cultivated in tropical America for its edible tuberous rhizome, the sweet potato.

Order 2. CUSCUTEÆ. Parasites destitute of chlorophyll, with filiform stems, which attach themselves to other plants by means of roots, and derive their nourishment from them: the small flowers are arranged in fascicles (Fig. 220 *b*): the corolla has imbricate æstivation: fruit a capsule with transverse dehiscence.

Cuscuta europæa, the greater Dodder, which occurs commonly on Nettles and Hops, is widely distributed: *C. epilinum* is the Flax Dodder, and *C. epithymum*, the lesser Dodder, occurs on various low-growing plants such as Clover, which it often destroys.

Order 3. POLEMONIACEÆ. Ovary trimerous and trilocular, with one erect or several oblique ovules in each loculus: capsule loculicidal. Mostly herbs without milky juice.

Polemonium cœruleum is Jacob's ladder; various species of Phlox are common garden plants.

Order 4. SOLANACEÆ. Ovary consisting of two obliquely placed carpels, bilocular, with numerous ovules attached to the septum: the septum sometimes projects so far into the cells that the ovary appears to be quadrilocular, as in Datura: ovules campylotropous; fruit a capsule with various dehiscence, or a berry: seed with endosperm. Herbs, occasionally woody plants, without milky juice. Inflorescence cymose, but complicated by the displacement of the bracts. Fig. 221 *B*, for instance, is a diagram of the inflorescence of Atropa; the main axis which terminates with the flower 1, bears a bracteole 1α and a lateral shoot terminating in the flower 2; this springs from the axil of a bract 1β, which, however, is not inserted at the base of its axillary shoot (the point of the arrow indicates its proper position), but is displaced upwards until it is close under the bracteole 2α; this displacement is repeated throughout the whole system of the cyme, so that in Atropa there are always two

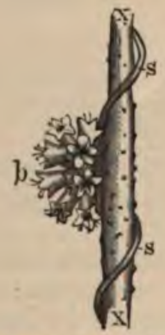


FIG. 220.—Stem of *Cuscuta europæa* (*s*), with inflorescence (*b*) winding round a stem of Hop (*x*).

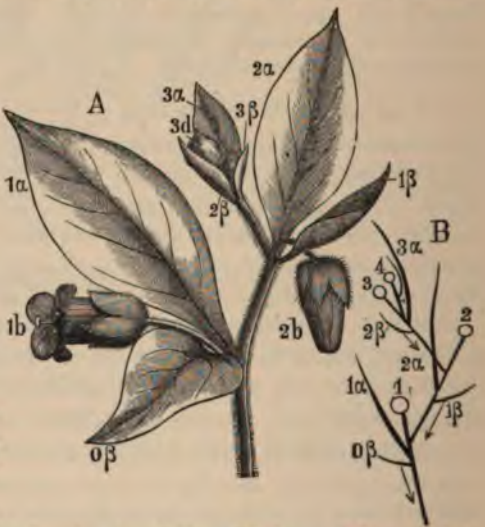


FIG. 221.—*A* Upper portion of a flowering stem of *Atropa Belladonna*. *B* Diagram of the same stem: 1 2 3 the flowers; α and β the bracteoles and bracts. From the axils of β spring the new floral axes, along which the bract β is displaced.

leaves below each flower, a larger one (Fig. 221 *A* 1*a*, 2*a*, and so on), which is the bracteole of the flower, and a smaller one (Fig. 221 *A* 0*β*, 1*β*, 2*β*, etc.), which is the bract from the axil of which the flowering-shoot springs. In other of the Solaneæ similar arrangements are found. Most plants of this order are poisonous.

Tribe 1. *Solaneæ.* Fruit a berry. In the genus Solanum the anthers are syngenesious: *S. Dulcamara*, the Bittersweet or Woody Nightshade, has a blue flower, and *S. nigrum* has a white flower; both are common: *S. tuberosum* is the Potato-plant. *Physalis Alkekengi*, the Winter Cherry, has an inflated red calyx which encloses the berry. *Lycopersicum esculentum* is the Tomato. The fruits of *Capsicum longum* and *annuum* are known as Chili Peppers. *Atropa Belladonna* is the Deadly Nightshade; the anthers are not syngenesious, and the corolla is campanulate; the berries are black and very poisonous. *Lycium barbarum* is a shrub belonging to Southern Europe which has become wild in places in the North.

Tribe 2. *Nicotianeæ.* Fruit a 2-valved loculicidal capsule.

Nicotiana Tabacum is the Tobacco plant (Fig. 138 *B*). Petunia is commonly cultivated.

Tribe 3. *Datureæ.* Capsule almost quadrilocular in consequence of the outgrowth of the septum, 4-valved.

Datura Stramonium is the Thorn-apple.

Tribe 4. *Hyoscyameæ.* Capsule dehisces transversely.

Hyoscyamus niger is the common Henbane.

Order 5. ASPERIFOLIÆ (BORAGINEÆ). Ovary consisting of two median carpels, spuriously quadrilocular in consequence of a constriction along the dorsal suture of each carpel (Fig. 222 *C*, *r*): the single style arises from the incurved apices of the carpels, and is surrounded at its base by the four loculi (Fig. 222 *B*): each loculus contains a single suspended anatropous ovule: when the fruit is ripe the loculi separate completely, and appear to be four achænia: seed without endosperm: the corolla usually has four scaly ligular appendages at the junction of the limb with the tube (Fig. 222 *b*): inflorescence cymose, scorpioid and often very complicated. Herbs or shrubs generally covered with harsh hairs and only rarely glabrous, *e.g.*, *Myosotis palustris*.

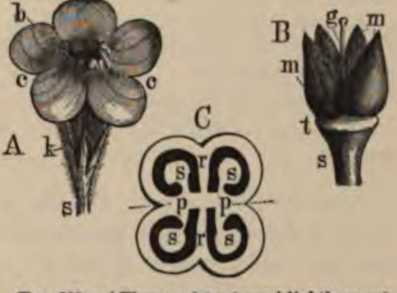


FIG. 222.—*A* Flower of Anchusa (slightly mag.): *k* calyx; *c* corolla; *b* the scaly appendages. *B* Fruit of Myosotis (mag.): *t* the receptacle; *m m* the four achænia; *g* the style. *C* Diagram of the quadrilocular ovary in trans. section: *r* the dorsal sutures; *p p* the placentas; *s* the ovules.

Sub-order 1. EHRETOIDEÆ. Style at the apex of the ovary.

Heliotropium peruvianum, a well-known garden plant with fragrant flowers.

Sub-order 2. BORAGINOIDEÆ. Style inserted between the four loculi.

Myosotis is the Scorpion-grass; *M. palustris*, the Forget-me-not, occurs in damp places, *M. sylvatica* in woods, and *M. arvensis* and others in fields. *Lithospermum arvense* (Gromwell), *L. officinale*, *Echium vulgare* (Viper's Bugloss), *Lycopsis arvensis* (Common Bugloss), *Cynoglossum officinale* (Hound's-tongue), are common weeds. *Borago officinalis* is the Borage. *Anchusa officinalis*, the Alkanet, is rare.

Cohort 4. **Gentianales.** Flowers actinomorphic: perianth and andrœcium usually 4- or 5-merous: corolla with frequently contorted æstivation (to the right): stamens inserted on the tube of the corolla: carpels two: leaves commonly decussate and exstipulate: formula $K(5)\ (C(5)\ A5)\ G^{\underline{(2)}}$.

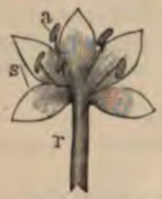


FIG. 223.—Corolla of *Erythræa Centaurium* spread out: *r* tube; *s* limb; *a* stamens.

Order 1. GENTIANEÆ. Carpels perfectly connate, forming a uni- or bilocular ovary: ovules parietal, numerous, anatropous: seed with endosperm. Usually herbs without milky juice: leaves almost always entire.

Sub-order 1. GENTIANEÆ. Leaves decussate: corolla with contorted æstivation.

Gentiana, the Gentian, has a bilobed stigma; it occurs in mountainous districts. Erythræa has a capitate stigma; *E. Centaurium*, the common Centaury, is common in pastures.

Sub-order 2. MENYANTHEÆ. Leaves spiral: corolla with valvate æstivation.

Menyanthes trifoliata, the Buckbean, with ternate leaves, is common in marshes.

Order 2. LOGANIACEÆ. Corolla with usually valvate æstivation. Ovary 2–4-locular, each loculus containing one or several ovules: seed with endosperm (Fig. 157 *A*). Mostly trees with opposite and usually exstipulate leaves.

Semen Strychni or *Nux vomica*, the seed of *Strychnos Nux vomica* in the East Indies, is extremely poisonous. The South American Indians poison their arrows with the sap of the cortex of *Strychnos guyanensis*, under the name of Curare.

Order 3. APOCYNEÆ. Corolla with contorted æstivation. The two carpels are usually connate only by their styles, which become free as they ripen: seed usually devoid of endosperm. Herbs or shrubs with milky juice.

Nerium Oleander is an ornamental shrub. *Vinca minor* and other species, the Periwinkles, are common creeping plants, wild and in gardens.

Order 4. Asclepiadeæ. Corolla with usually imbricate æstivation. The two carpels usually form two distinct monomerous ovaries: styles short, united into one stigma: stamens connate, forming a tube surrounding the gynœcium, having pouch-shaped (Fig. 224 *B*, *t*) and spur-shaped (Fig. 224 *B*, *h*) appendages: anthers 2–4-locular; the pollen of each sac forms a mass (pollinium), and the masses of each pair of contiguous sacs adhere (Fig. 224 *C*, *p*, *p*) and are conveyed by insects to the stigmas: ovules numerous, attached to the ventral suture: seed usually without endosperm. Generally woody plants, often climbers with milky juice.

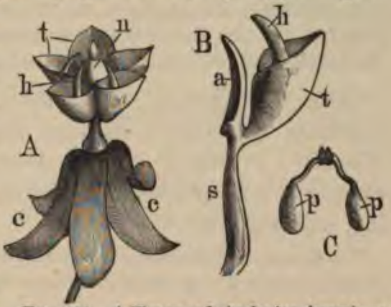


Fig. 224.—*A* Flower of Asclepias (mag.): *c* the reflexed corolla; *n* stigma; *h* the spurs, *t* the pouches of the stamens. *B* A solitary stamen; *a* the anther. *C* Pollen-masses, p and p.

Asclepias syriaca and other species are grown in gardens, also *Hoya carnosa*, the Wax flower. Stapelia has a fleshy cactus-like stem.

Order 5. Oleaceæ. Calyx and corolla usually 4-merous, sometimes wanting; corolla with valvate æstivation: stamens and carpels 2, alternate: ovary bilocular: ovules, 2 in each loculus, suspended and anatropous: fruit a capsule, a berry, or a drupe: seed with endosperm: stem woody: leaves always decussate.

Sub-order 1. Oleineæ. Fruit a berry or a drupe.

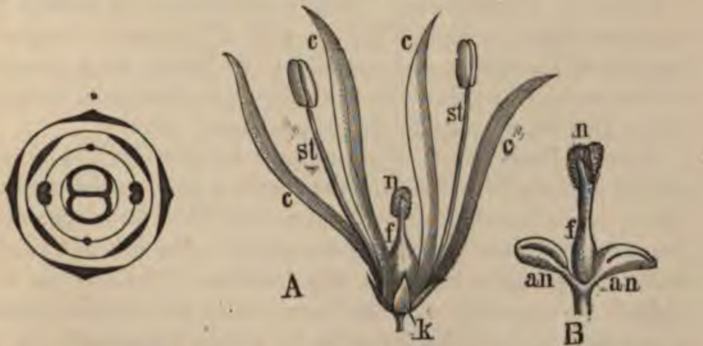


Fig. 225.—*A* Flower of *Fraxinus Ornus* (enlarged): *k* calyx; *c* corolla; *st* stamens; *f* ovary; *n* stigma. *B* Hermaphrodite flower of *Fraxinus excelsior*, the common Ash; *an* anthers; *f* ovary; *n* stigma (enlarged). Floral diagram of the Oleaceæ.

Ligustrum has a baccate fruit; *L. vulgare*, the Privet, is a common shrub. Olea has a drupaceous fruit; *O. europæa* is the Olive-tree of the East and of Southern Europe.

Sub-order 2. FRAXINEÆ. Fruit a capsule, or winged and indehiscent (samara). The genus Fraxinus has a winged fruit; in *F. excelsior*, the common Ash, the perianth is suppressed and the flowers are polygamous; in *F. Ornus*, the Manna Ash of Southern Europe, the perianth is complete, and the corolla is deeply cleft (Fig. 225 *A*). The fruit of the genus Syringa is a 2-valved capsule; the limb of the corolla is 4-lobed; *S. vulgaris* is the Lilac.

Order 6. JASMINEÆ. Calyx and corolla 4–5-merous; corolla with imbricate æstivation; stamens and carpels 2, alternate: ovary bilocular: ovules, 2 in each loculus, erect, anatropous; fruit a capsule or a berry: seed without endosperm. Shrubs, often climbing, with scattered leaves.

The flowers of *Jasminum grandiflorum* and other species belonging to Southern Europe contain a very fragrant ethereal oil.

Cohort 5. **Ebenales.** Flowers actinomorphic, 4–8-merous; formula often $K(4)\ C(4)\ A4 + 4,\ G^{\underline{(4)}}$, the outer stamens being sometimes suppressed: stamens epipetalous. carpels opposite to the sepals: ovary multilocular, with one or two suspended ovules in each loculus: fruit usually fleshy.

Order 1. SAPOTEÆ. Tropical trees with milky juice.

Isonandra Gutta, an East Indian tree, yields Gutta-percha.

Order 2. EBENACEÆ. Trees; flowers generally diclinous.

Diospyros Ebenum in the East Indies yields the wood known as Ebony.

Order 3. STYRACEÆ. Flowers perigynous or epigynous: trees.

Gum Benzoin is the resin of *Styrax Benzoin* in the East Indies.

Cohort 6. **Primulales.** Flowers actinomorphic, usually pentamerous: formula $K(5)\ (C(5)\ A0 + 5)\ G^{\underline{(5)}}$: stamens inserted on the tube of the corolla and opposite to its lobes: ovary consisting of five connate carpels which are opposite to the sepals, unilocular, with a free central placenta or a single central ovule.

Order 1. PRIMULACEÆ. Style single: ovules indefinite, on a free central placenta (Fig. 148 *G*): the corolla is gamopetalous, tubular below, expanding above into a 5-lobed limb which is wanting only in Glaux: the anthers (Fig. 226 *a*) are adnate to the tube of the corolla and are opposite to its lobes; this position of the stamens is explained by supposing that an outer whorl of stamens (which is represented in the following order by petaloid staminodes) is here suppressed: fruit a capsule. Herbaceous plants with conspicuous flowers.

The genus Primula has a 5-valved dehiscent capsule, and a 5-cleft calyx. *Primula elatior* and *P. veris* are the Oxlip and the Cowslip; they are remarkable in that they are heterostyled; that is, that in some flowers (Fig. 226 *B*) the style is as long as the tube of the corolla, and the stamens are situated at about half the height, whereas in others (Fig. 226 *A*) the style is only half the length and the anthers are inserted in the throat of the corolla: fertilisation only takes place when the pollen of the anthers which correspond in their position to the length of the styles is applied to their stigmas. The capsule of *Anagallis arvensis*, the Pimpernel, dehisces transversely (pyxidium). *Cyclamen europæum*, the Sow-bread, has an underground tuber; the lobes of the corolla are reflexed. Lysimachia has a deeply 5-cleft calyx. Trientalis has usually a 7-merous flower.

Order 2. MYRSINEÆ. These plants differ from the preceding in that the fruit is baccate and the stem woody.

Ardisia, with red berries, is a well-known ornamental plant.

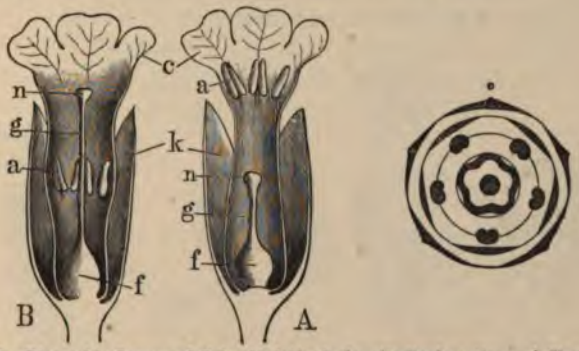


FIG. 226.—Dimorphic flowers of *Primula elatior* in longitudinal section. *A* Short-styled. *B* Long-styled form; *k* calyx; *c* corolla; *a* anthers; *f* ovary; *g* style; *n* stigma. Floral diagram of Primula.

Order 3. PLUMBAGINEÆ. Styles five: there is a single basal ovule in the cavity of the ovary: flowers often small, in dense inflorescences with numerous bracts.

In the genus Armeria the flowers are in capitula, which are surrounded by an involucre formed of the lower scarious bracts; *A. vulgaris*, the Thrift, occurs on sandy soils. Statice, with one-sided spikes, occurs on sandy sea-shores. Plumbago occurs in Southern Europe and in the East Indies.

Cohort 7. **Ericales.** Flowers 4–5-merous, actinomorphic: stamens usually in two whorls, and usually hypogynous: carpels opposite to the petals: formula $K(\mathrm{n})\ C(\mathrm{n})\ A\mathrm{n}+\mathrm{n} \mid G(\mathrm{n})$, where $\mathrm{n}=4$ or 5: ovary superior or inferior, multilocular, with large projecting axile placentæ: seed with endosperm: anthers usually appendiculate.

Order 1. ERICACEÆ. Anthers generally opening by two pores at the top (Fig. 227 *A*), furnished with appendages: fruit a loculicidal capsule, or fleshy.

The genus Erica has a 4-lobed corolla and a loculicidal capsule: *Erica cinerea*, *Tetralix*, and *Calluna vulgaris*, the common Heath or Ling, occur on heaths and moors. *Arctostaphylos Uva Ursi* is the Bearberry; its fruit is a berry. *Arbutus Unedo*, the so-called Strawberry-tree, belongs to Southern Europe.

Order 2. EPACRIDEÆ. The whorl of stamens opposite the petals is usually wanting: the anthers open by one fissure only. Australian plants.

Order 3. RHODORACEÆ. The anthers usually open by two apical pores, and have no appendages: fruit a septicidal capsule.

Rhododendron ferrugineum and *hirsutum*, the Alpine Rose, are wild on the Continent; other species of Rhododendron and Azalea from India and the southern shores of the Black Sea are cultivated.

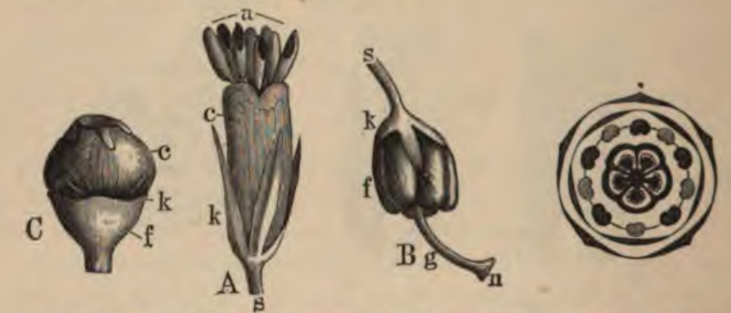


FIG. 227.—*A* Flower of Erica: *s* pedicel; *k* calyx; *c* corolla; *a* anthers. *B* Fruit of *Pyrola rotundifolia*: *s* pedicel; *k* calyx; *f* fruit, the loculi of which alternate with the sepals; *g* style; *n* stigma. *C* Flower of *Vaccinium Myrtillus*: *f* ovary (inferior); *k* calyx; *c* corolla. Floral diagram of Erica: the stamens opposite to the petals are faintly shaded.

Order 4. PYROLACEÆ. Sepals more or less distinct: petals commonly connate at the base only: anthers without appendages, generally dehiscing transversely or by pores: fruit a loculicidal capsule: seed minute, with an extremely small embryo, consisting of only a few cells and a relatively massive integument. Saprophytes containing chlorophyll.

Pyrola rotundifolia, *secunda*, *minor*, and *uniflora*, the Winter-greens, are found in woods.

Order 5. MONOTROPEÆ. Saprophytes devoid of chlorophyll, with scale-like leaves, otherwise resembling the Pyrolaceæ.

Monotropa Hypopitys, the Bird's-nest, is not very common in England.

Order 6. Vacciniеæ. Ovary inferior (Fig. 227 *C*): anthers with appendages (Fig. 141 *B*), usually opening by two pores: fruit a berry.

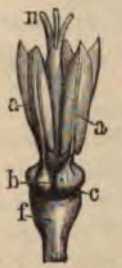
Vaccinium Vitis-Idæa is the red Whortleberry or Cowberry; it usually blossoms and bears fruit twice in the year. *V. Myrtillus* is the Bilberry or Whortleberry, with deciduous leaves. *V. Oxycoccos*, the Cranberry, and *V. uliginosum*, the great Bilberry, are low shrubs occurring on moors.

SERIES II. EPIGYNÆ.

Ovary inferior.

Cohort 1. **Campanales.** Flowers actinomorphic or zygomorphic, pentamerous: sepals leafy and narrow: stamens usually free from the corolla, but often connate: ovary of two to five carpels, inferior: formula $K(5)\ C(5)\ A(5)\ G_{\overline{(2)}}$ to $_{\overline{(5)}}$.

Order 1. Campanulaceæ. Flowers usually actinomorphic: stamens five, often connate at the base: ovary usually trilocular, with numerous ovules; placentation axile: fruit a capsule: seed with endosperm. Mostly herbs with milky juice.



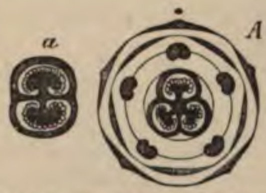


Fig. 229.—Floral diagram of Lobelia: *a* gynœcium of Lobelia.

Fig. 228.—Andrœcium and gynœcium of Campanula: *f* inferior ovary; *c* insertion of the corolla; *a* anthers; *b* expanded base of the stamens; *n* stigmas (mag.).

Campanula rotundifolia, the Hare-bell, *glomerata*, and other species are common in fields, on heaths, etc., etc.: *C. media* is the Canterbury-bell cultivated in gardens. *Phyteuma orbiculare*, *spicatum*, the Rampions, are indigenous in parts of England; the flowers are in capitula, and the calyx is deeply 5-cleft with spreading teeth: nearly allied is the genus Jasione; *J. montana*, the Sheep's-bit, is common in England. Specularia has a rotate corolla; *S. speculum*, Venus's Looking-glass, is cultivated.

Order 2. Lobeliaceæ. Flowers zygomorphic (Fig. 230): the corolla commonly forms a tube which is more or less cleft on one side, and the limb is divided into two lips, the lower one consisting of three lobes (Fig. 230 *A*, *u*) and the upper of two smaller ones (Fig. 230 *A*, *o*): at their first formation the position of these parts is exactly the reverse, but in the course of development the pedicel undergoes torsion, so that those parts which are originally posterior become anterior, and *vice versâ*: anthers syngenesious (Fig. 230 *B*, *sr*) and unequal in consequence of the zygomorphic structure of the flower: ovary 1, 2, or 3-locular, with numerous anatropous ovules: fruit a capsule: seed with endosperm. Herbs or shrubs usually with a milky juice.

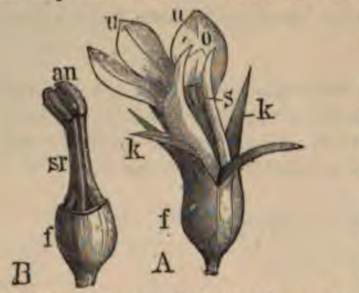


FIG. 230.—*A* Flower of Lobelia: *f* ovary; *k* calyx; *o* upper, *u* under lip of the corolla; *s* stamens. *B* Andrœcium and gynœcium of the same: *sr* tube formed by the stamens; *an* anthers (mag.).

L. Dortmanni, the Water Lobelia, and *L. urens*, the acrid Lobelia, occur in some parts of England.

Cohort 2. **Asterales.** Calyx inconspicuous, often wanting: stamens epipetalous, alternating with the segments of the corolla: ovary unilocular, ovule solitary.

Order 1. VALERIANEÆ. Flowers zygomorphic or irregular, originally pentamerous: calyx wanting, or sometimes assuming the form of a hairy corona of ten rays, called a pappus, which is not developed until after flowering (Fig. 231 *B*, *p*), during flowering it remains short and infolded (Fig. 231 *A*, *k*): only three stamens are usually developed: carpels three, forming a trilocular ovary, of which, however, never more than one loculus developes; ovule single, suspended (Diagram *A*, Fig. 231): seed without endosperm: leaves decussate, exstipulate.

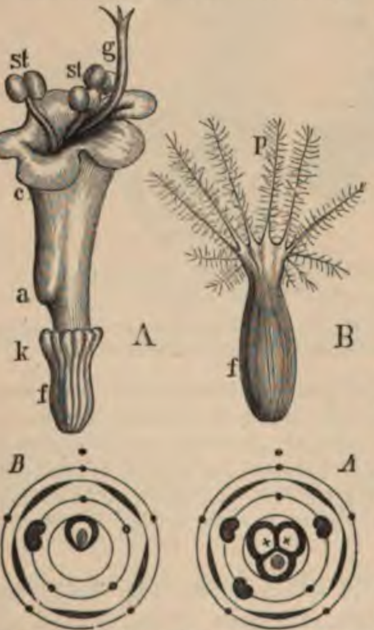


FIG. 231.—*A* Flower, *B* Fruit of Valerian: *f* ovary; *k* calyx; *c* corolla; *a* spur; *st* stamens; *g* style; *p* pappus. Floral diagrams, *A* of Valerian; *B* of Centranthus.

Valeriana officinalis, and *dioica*, are common in damp places. Valerianella has a toothed calyx-limb; many species are common in fields: *Valerianella olitoria*, Cornsalad, or Lamb's lettuce, is eaten. *Centranthus ruber* is an ornamental plant; only one stamen and one carpel are developed (Fig. 231, Diagram *B*); at the base of the tube of the corolla is a spur which is indicated in Valeriana by a protuberance.

Order 2. DIPSACEÆ. Flower originally pentamerous, and surrounded by an epicalyx (Fig. 232 *k'*) formed of connate bracteoles: calyx often plumose or bristly (Fig. 232 *k*): corolla bilabiate: stamens only four, the posterior one being suppressed: ovary unilocular, with one suspended ovule: seed with endosperm: leaves decussate, exstipulate: flowers in a dense capitulum surrounded by an involucre: the outer florets are usually ligulate: the receptacle may or may not bear scaly bracteoles: fruit invested by the epicalyx which is cleft longitudinally.

Dipsacus, the Teazle, has a calyx without bristles; the capitula of *Dipsacus Fullonum* are used in finishing woollen cloth, for the sake of the strong hooked spines of the bracteoles: *D. silvestris* is common on waste ground. Scabiosa has paleæ, and the projecting limb of the epicalyx is dry; *S. Columbaria* is common in pastures. In Succisa the limb of the epicalyx is herbaceous; *S. pratensis* occurs in damp meadows. Knautia has paleæ; epicalyx entire: *K. arvensis* is common in fields.

Order 3. COMPOSITÆ. The flowers are always collected into many-flowered capitula (sometimes only 1-flowered): in the same head, hermaphrodite, female, and asexual flowers generally occur: ovary inferior, unilocular, with a basal, erect, anatropous ovule: the calyx is rarely present in the form of small leaves or scales (Fig. 235 *D, p*); more commonly it is a crown of simple or branched hairs (Figs. 233 *p*, and 235 *A, E, p*), and is not developed till after the flowering is over; it is termed the pappus: sometimes the calyx is wholly wanting: corolla tubular, either regular, and 5-toothed (Figs. 233 *A, c*, 235 *C, m, c*), or expanded at the upper end into a lateral limb with 3 or 5 teeth (Figs. 233 *B*, 235 *B, ra*), (Fig. 235 *A, c*), when it is said to be *ligulate:* the stamens are short, inserted upon the corolla (Fig. 233 *A, st*); the anthers are elongated and syngenesious, forming a tube through which the style passes (Figs. 233 *A, a*, 235 *A, a*): this is bifid at its upper end (Figs. 233 *A, n*, 235 *A* and *C n*): on each of these branches the stigmatic papillæ are arranged in two rows: in the wholly female flowers the styles are usually shorter (Fig. 233 *B, g*): fruit an inferior achene (cypsela), crowned by the pappus (Fig. 235 *E* and *D, p*) when it is present (Fig. 235 *F, f*) sometimes the fruit has its upper end prolonged into a beak, and its surface is covered with ridges or spines (Fig. 235 *E*, *h*): seed without endosperm.

Usually herbs with scattered (more rarely decussate), exstipulate leaves, often with milky juice. The capitula are always surrounded by a number of bracts forming an involucre (Fig. 235 *B*, *i*). The scaly bracteoles of the individual florets (paleæ) may be present or wanting (Fig. 235 *C*, *d*).

The Compositæ are classified according to the form of the flowers and to the distribution of the sexes in the inflorescence.

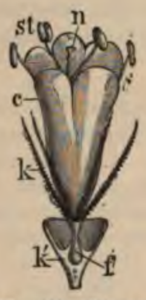
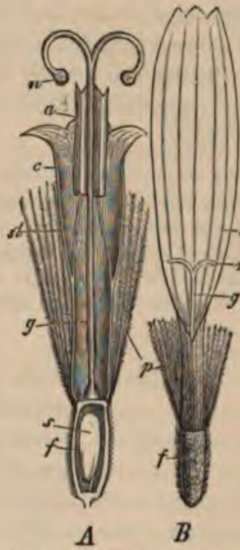


FIG. 232.—Flower of Scabiosa (mag.): *f* ovary; *k'* epicalyx (long. sect.); *k* calyx; *c* corolla; *st* stamens; *n* stigma.



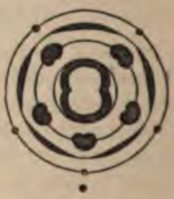


FIG. 234.—Floral diagram of Compositæ.

FIG. 233.—Flower of Arnica (mag.). *A* Floret from the centre (disc) (longitudinal sect.). *B* Marginal floret (ray); *f* ovary; *p* pappus; *c* corolla; *a* anthers; *n* stigma; *g* style; *s* ovule.

Sub-order 1. TUBULIFLORÆ. The capitula either consist entirely of hermaphrodite tubular florets (by tubular flowers are meant those with a regular 5-toothed corolla) or the central florets (florets of the disc) are tubular and hermaphrodite (Fig. 233 *A*), whereas the florets of the ray are ligulate and female or asexual, and form one or two rows (Figs. 233 *B*, 235 *B*, *ra*).

Tribe 1. *Eupatorieæ.* Leaves mostly opposite: flowers all tubular, hermaphrodite: the branches of style narrow; papillæ extending to the middle.

Eupatorium Cannabinum, the Hemp Agrimony, is common in damp places.

Tribe 2. *Tussilagineæ.* Leaves alternate, radical: ray-florets female, sometimes ligulate: the branches of the style are bifid at the tips.

Petasites vulgaris, the Butter-bur, and *Tussilago Farfara*, the Colt's-foot, are common in wet fields.

Tribe 3. *Asteroideæ.* Leaves alternate: ray-florets female or neuter, generally ligulate: branches of the style hairy above, papillæ extending to where the hairs begin. Many species of Aster, belonging chiefly to North America, are cultivated as ornamental plants, as also *Callistephus Chinensis*, commonly known as the China Aster. *Erigeron acris*, *alpinus* and *canadensis* occur in England; the last is an imported weed. *Bellis perennis*, the Daisy, is universal. Solidago is the Golden Rod.

Tribe 4. *Senecionideæ*. Leaves alternate: ray-florets in one row, ligulate, female, rarely absent: branches of the style tufted at the tips.

Senecio vulgaris, the Groundsel, is universal as a weed. *Arnica montana* occurs in Alpine woods. Two species of Doronicum have become naturalized in England.

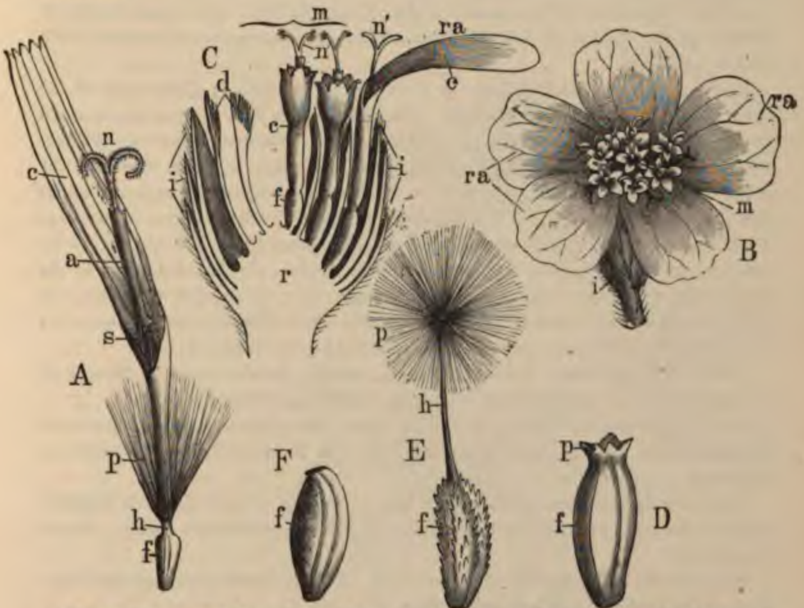


FIG. 235.—Flowers of Compositæ: *f* fruit or ovary; *h* its beak; *p* pappus; *c* corolla; *s* stamens; *n* stigmas. *A* Ligulate flower of Taraxacum, with a 5-toothed corolla-limb, hermaphrodite. *B* Capitulum of Achillea (mag.): *ra* floret of the ray, with ligulate 3-toothed corolla, female; *m* hermaphrodite florets of the disc, with a 5-toothed tubular corolla; *i* involucre. *C* Longitudinal section more highly magnified: *r* receptacle; *i* involucre; *d* bracteoles (paleæ); *ra* floret of the ray; *m* floret of the disc; *n′* stigmas of the female flowers. *D* Fruit of Tanacetum, with a scaly pappus. *E* Of Taraxacum, with a hairy pappus. *F* Of Artemisia, without a pappus (mag.).

Tribe 5. *Anthemideæ*. Leaves alternate: ray-florets female, ligulate or tubular: branches of style tufted at the tips: pappus 0, or minute.

Artemisia Absynthium, Wormwood, *A. vulgaris* and *campestris* are common; *Chrysanthemum Leucanthemum*, the Ox-eye Daisy, is common in fields. *Matricaria Chamomilla*, the Wild Chamomile, has a hollow conical receptacle destitute of paleæ. *Anthemis nobilis*, the Common Chamomile, has a receptacle bearing paleæ, as also *A. arvensis*, the Corn Chamomile. *Achillea Millefolium* is the Milfoil. *Tanacetum vulgare* is the Tansy.

Tribe 6. *Helianthеæ*. Leaves opposite: ray-florets 0 or ligulate, yellow, female or neuter: branches of style as in Asteroideæ. Bidens is common in wet places. Galinsoga is naturalized in England.

Helianthus annuus is the Sunflower; oil is extracted from the seeds: the tubers of *H. tuberosus*, a West Indian species, are rich in inulin, and serve as a vegetable and for fodder (Jerusalem Artichokes).

Tribe 7. *Inuleæ*. Leaves alternate: ray-florets ligulate, female, yellow: branches of style as in Asteroideæ.

Inula Helenium is the Elecampane.

Tribe 8. *Cynareæ*. Flowers all tubular, the outer ones sometimes female or neuter:| style thickened below the branches: leaves generally armed with spines, alternate.

Arctium Lappa, the Burdock, is common by roadsides; the leaves of the involucre are hooked and spinous. *Carduus nutans* and *crispus* are common (true) Thistles; *Carduus* (*Cirsium*) *lanceolatus*, *palustris*, *pratensis* (Plume-thistles), are common in damp districts. *Carlina vulgaris* is the Carline; the inner leaves of the involucre, which are white, fold over the flower head under the influence of moisture, but in drought spread widely open. *Centaurea Scabiosa* and *nigra*, the Knapweeds, are common everywhere. *C. Cyanus* is the Corn-flower or Blue-bottle, occurring in wheat fields. *Cynara Scolymus* is the Artichoke; the flower-buds are eaten as a vegetable. *Carthamus tinctoria*, the Safflower, is used in dyeing. In Echinops, the Globe-Thistle (exotic), numerous one-flowered capitula are collected into one large spherical head.

Tribe 9. *Gnaphalieæ*. Leaves alternate, entire: bracts scarious: flowers all tubular, the outer ones female: branches of style papillose at the tips.

In Gnaphalium, the Cud-weed, and in Filago, the capitula contain female and hermaphrodite flowers, but in Antennaria, the Everlasting, the flowers are diœcious.

Sub-order 2. LABIATIFLORÆ. The hermaphrodite florets have a bilabiate corolla; the male and female florets have a ligulate or a bilabiate corolla. South American.

Sub-order 3. LIGULIFLORÆ (CICHORIACEÆ). All the florets are hermaphrodite; limb of the corolla 5-toothed and ligulate (Fig. 235 *A*).

Taraxacum officinale, the Dandelion, is the commonest of wild flowers. *Lactuca sativa* is the Lettuce. *L. Scariola*, *virosa*, and others, are common in waste places. *Scorzonera hispanica* is eaten as a vegetable. *Tragopogon porrifolium*, the Salsafy, and *T. pratensis*, the Goat's beard, are common. *Cichorium Intybus*, the Chicory, is found by roadsides; the roasted roots are mixed with Coffee: *C. endivia* (Endive) is a vegetable. To this group belong also the genera Hieracium, Sonchus, Crepis, Lapsana.

Cohort 3. **Rubiales.** Leaves generally opposite: calyx generally present and incised: stamens epipetalous, alternate with the segments of the corolla: ovary 2–8-locular, ovules 2—∞.

Order 1. RUBIACEÆ. Flowers actinomorphic, 4- or 5-merous: calyx leafy or suppressed: corolla with valvate æstivation: ovary

1- or 2-locular, consisting of two carpels, 1- or many-seeded: seed usually containing endosperm: leaves decussate, stipulate: stipules similar to the true leaves (Fig. 236 *A*, *n n*): the true leaves are distinguished by the branches which arise in their axils (Fig. 236 *A*, *f f*, *s s*).

Sub-order 1. STELLATÆ. Stipules large and leafy: loculi 1-seeded.

Galium, Bedstraw, has a rotate corolla and an inconspicuous calyx, usually tetramerous: *G. verum*, *Mollugo*, *Aparine*, and others are common in hedges and pastures. Asperula has an infundibuliform corolla, but in other respects the flower resembles that of Galium; *A. odorata*, the Wood-ruff, is common. *Rubia tinctorum*, the dyer's Madder, has a pentamerous flower, a rotate corolla, and a baccate fruit; it is used in dyeing and largely cultivated; it is indigenous in Southern Europe and the East; it is closely allied to the British species *R. peregrina*, the Wild Madder. Sherardia has a conspicuous calyx; *S. arvensis*, the Field Madder, is found in cultivated and waste places.

Sub-order 2. COFFEACEÆ. Stipules scaly: loculi 1-seeded.

Coffea arabica, the Coffee-tree of Africa, is grown in the tropics; the fruit, a berry, contains one or two seeds; the so-called coffee-bean is the seed which consists of endosperm and contains a small embryo. Cephaelis yields Ipecachuana.

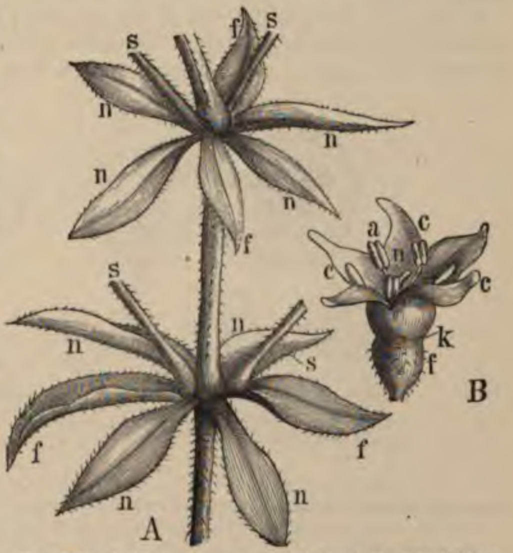


FIG. 236.—*A* Portion of a stem of *Rubia tinctorum*: *f f* the decussate leaves with the young shoots (*s s*) in their axils; *n n* the segmented stipules resembling the leaves (nat. size). *B* Flower (mag.): *f* ovary; *k* calyx (rudimentary); *c* corolla; *a* anthers; *n* stigma.

Sub-order 3. CINCHONEÆ. Stipules scaly: loculi many-seeded.

Various species of Cinchona, indigenous to the eastern slopes of the Andes, but cultivated in Java and the East Indies, yield the cinchona-bark from which Quinine is prepared.

Order 2. CAPRIFOLIACEÆ. Flowers usually pentamerous, actinomorphic or zygomorphic: corolla usually with imbricate æstivation; ovary 2–5-locular: ovules suspended: fruit baccate; seed with endosperm: leaves opposite, usually exstipulate. Mostly trees or shrubs.

Tribe 1. *Sambuceæ.* Corolla rotate, usually actinomorphic; one ovule in each loculus.

Sambucus, the Elder, has a 5-partite corolla, and 3–5 seeds in the berry; *S. nigra* is the Elder. Viburnum has a 5-partite corolla, and 1 seed in the berry; *V. Lantana* and *V. opulus*, the Guelder Rose, are common; a form of the last species is cultivated, in which all the flowers (and not merely those at the circumference of the corymb as in the original species) have large corollas, and are barren. *Adoxa moschatellina* is a small plant occurring in damp woods; the stamens are branched.

Tribe 2. *Lonicereæ.* Corolla tubular, usually zygomorphic: loculi containing several ovules.

Lonicera, the Honey-suckle, has 2–3-locular ovary; *L. Caprifolium* and *Periclymenum*, with a climbing stem, are well-known garden shrubs; in many species the fruit of two adjacent flowers grow together to form a single berry (*e.g.*, *L. alpigena*). *Symphoricarpus racemosus*, the Snowberry, has a 4–5-locular ovary and white berries; it is a common ornamental shrub. Diervilla has a bilocular capsule; *D. Canadensis* and *rosea* are ornamental shrubs. *Linnæa borealis* is a small creeping plant in Norway and in the Alps.

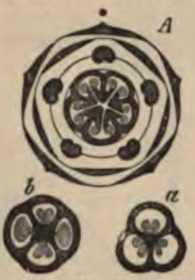


FIG. 237.—Floral diagram of Caprifoliaceæ. *A* Leycesteria: *a* gynœcium of Lonicera; *b* of Symphoricarpus.

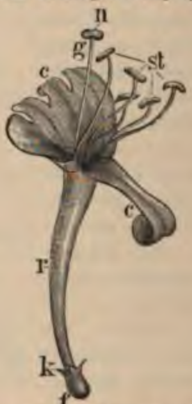


FIG. 238.—Flower of *Lonicera Caprifolium*: *f* ovary; *k* calyx; *r* tube; *c c* the five lobes of the limb; *st* stamens; *g* style; *n* stigma.

SUB-CLASS III. POLYPETALÆ.

Flowers usually hermaphrodite: perianth usually consisting of calyx and corolla, the petals being free.

SERIES I. CALYCIFLORÆ.

Flowers epigynous or perigynous: calyx usually gamosepalous: stamens definite or indefinite: gynœcium syncarpous or apocarpous.

Cohort 1. **Umbellales.** Flowers usually actinomorphic, epigynous, with generally a single whorl of stamens opposite to the sepals: calyx inconspicuous: ovary bilocular, with one ovule in each loculus: a disc between the stamens and the styles: inflorescences usually umbellate: seed containing endosperm: leaves exstipulate.

Order 1. UMBELLIFERÆ. Formula, $K5$, $C5$, $A5$, $G_{\boxed{2}}$: the calyx is generally very small, often hardly visible; the corolla consists of five rather small white or yellow petals; occasionally the outermost petals of the flowers at the circumference of the umbel are larger than the others, and the umbel is then termed *radiate:* stamens five; ovary inferior, bilocular: the base of the two styles is fleshy and thickened, forming an epigynous disc (Fig. 239 *A d*); one suspended ovule in each loculus of the ovary (Fig. 148 *E*): the fruit, when ripe, splits into two mericarps, each loculus of the ovary being permanently closed by a median septum (Fig. 240 *a*). The structure of the pericarp is an important characteristic for the classification of the family. The fruit is commonly either oval in form (Fig. 240), or compressed (Fig. 239 *B*), or nearly spherical (Fig. 239 *E*): its surface bears longitudinal ridges (*costæ*), five generally on each mericarp; of these, two run along the margins (Fig. 239 *B*, *C*, *D*, *rr*), and the other three along the dorsal surface

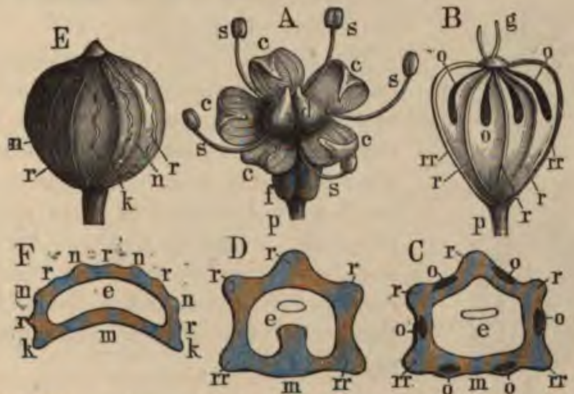


FIG. 239.—*A* Flower of Fœniculum (mag.): *f* ovary; *c* corolla; *s* stamens; *d* disc. *B* Fruit of Heracleum: *p* pedicel; *g* style; *r r r* ridges (costæ): *rr* marginal ridges; *o* oil-ducts (vittæ) (mag.). *C* Transverse section of mericarp of *Carum Carui: m* surface that comes into contact with the other mericarp; *o* vittæ; *e* endosperm. *D* Transverse section of mericarp of Conium. *E* Fruit of Coriandrum: *k* margins of the surface along which the two mericarps are in contact; *r* ridges; *n* secondary ridges. *F* Section of a mericarp (mag.).

(Fig. 239 *B, C, D, r*). In the spaces between the ridges, which form furrows, lie oil-ducts or receptacles (*vittæ*) (Fig. 239 *B, C, o*), and sometimes other secondary ridges (Fig. 239 *E, F, n*). The mericarp when ripe is filled by the seed, of which the larger part consists of endosperm (Fig. 239 *C, D, F, e*) enclosing a small embryo. According to the form assumed by the endosperm, the following groups may be distinguished: the *Orthospermeæ*, in which the surface of the endosperm which is directed towards the plane of junction of the two mericarps, is flat or convex, as in Carum (Fig. 239 *C*): the *Campylospermeæ*, in which the endosperm is concave towards the same plane, as in Conium (Fig. 239 *D*), and the *Cœlospermeæ*, in which the whole endosperm is curved, so that it is seen to be concave towards this plane both in longitudinal and in transverse section, as in Coriander (Fig. 239 *F*).

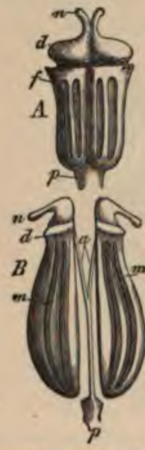


FIG. 240.—Fruit of *Carum Carui*. *A* Ovary of the flower (*f*). *B* Ripe fruit. The two loculi have separated so as to form two mericarps (*m*). Part of the septum constitutes the carphophore (*a*).

The flowers, with few exceptions (Astrantia and Eryngium), are in compound umbels; in some few cases, as in Daucus, there is a solitary terminal flower which is black in colour: an involucre and involucels are largely developed in some species, in others they are wholly wanting. The hollow stem bears large leaves with generally well-developed sheaths and much-divided laminæ. Rarely the leaves are entire and amplexicaul, as in Bupleurum.

Sub-order I. ORTHOSPERMEÆ.

1. Umbels simple.

Tribe 1. *Hydrocotyleæ*. Fruit laterally compressed. The genus Hydrocotyle consists of marsh-plants with peltate leaves.

Tribe 2. *Saniculeæ*. Fruit nearly cylindrical. This group includes the genera Astrantia, Eryngium, and Sanicula.

2. Umbels compound.

Tribe 3. *Ammineæ*. Fruit without secondary ridges, laterally compressed: Bupleurum, Petroselinum, Apium, Ægopodium, Carum, Cicuta, Sium.

Tribe 4. *Seselineæ*. Fruit without secondary ridges, circular in transverse section: Æthusa, Fœniculum, Œnanthe, Seseli, Meum.

Tribe 5. *Angeliceæ*. Fruit without secondary ridges, compressed in the median plane, the lateral primary ridges winged, the wings of the two mericarps divergent: Levisticum, Angelica, Archangelica.

Tribe 6. *Peucedaneæ*. Fruit without secondary ridges, compressed in the median plane, the lateral primary ridges winged, the wings of the two mericarps apposed: Peucedanum, Imperatoria, Anethum, Pastinaca, Heracleum.

Tribe 7. *Silerineæ.* Each mericarp has four secondary ridges: Siler.

Tribe 8. *Thapsieæ.* Each mericarp has four secondary ridges, of which the external ones at least are winged: Laserpitium.

Tribe 9. *Daucineæ.* The secondary ridges are spinous: Daucus.

Sub-order II. CAMPYLOSPERMEÆ.

Tribe 10. *Caucalineæ.* Secondary ridges spinous: Caucalis.

Tribe 11. *Scandiceæ.* Fruit without secondary ridges, laterally compressed, usually beaked: Anthriscus, Chærophyllum, Myrrhis.

Tribe 12. *Smyrnieæ.* Fruit without secondary ridges, unbeaked: Conium, Smyrnium.

Sub-order III. CŒLOSPERMEÆ.

Tribe 13. *Coriandreæ.* Fruit spherical; secondary ridges more prominent than the wavy primary ridges: Coriandrum.

Anthriscus silvestris, Carum Carui, the Caraway, *Heracleum spondylium,* the Cow-Parsnip, *Ægopodium Podagraria, Pastinaca sativa,* are common in meadows and woods. The following are cultivated: *Apium graveolens,* Celery; *Petroselinum sativum,* Parsley; *Daucus Carota,* the Carrot; *Pastinaca oleracea,* the Parsnip; *Anthriscus cerefolium,* the Chervil. The following are poisonous: *Conium maculatum,* the Hemlock; *Cicuta virosa,* the Water-Hemlock; *Æthusa Cynapium,* Fool's Parsley.

Order 2. ARALIACEÆ. Flowers generally pentamerous; stamens sometimes more numerous; carpels more or less numerous: fruit a berry or a drupe. Shrubs, sometimes climbers, with scattered palmate leaves.

Hedera Helix, the Ivy, does not blossom till it is some years old: the umbels are borne on erect branches, the leaves of which are entire. *Fatsia papyrifera* is used in Japan for making a kind of paper known as rice paper; it is made from the pith.

Order 3. CORNACEÆ. Flowers tetramerous, with a dimerous bilocular ovary: fruit usually a drupe. Shrubs with woody stems and entire opposite leaves.

Cornus mas, the Cornel, has yellow flowers which bloom before the unfolding of the leaves, and a red fruit. *C. sanguinea* and *suecica* are common shrubs. *Aucuba japonica* has coriaceous leaves, diœcious flowers, and a baccate fruit.

Cohort 2. **Ficoidales.** Affinity doubtful. Flowers epigynous or perigynous, with the very numerous petals and stamens, and often the sepals also, arranged spirally: ovary uni- or multilocular: placentas parietal or basilar.

Order 1. CACTEÆ. Flowers acyclic, epigynous, with numerous sepals, petals, and stamens, which gradually pass into each other: ovary unilocular, with three or more parietal placentæ: ovules horizontal; endosperm little or none: stems of the most various forms: leaves usually represented by tufts of spines. All are indigenous to tropical America, but many have been introduced into the eastern hemisphere.

Mamillaria has a spherical or cylindrical stem on which tubercles, arranged spirally and bearing spines, represent the leaves. Echinopsis and Echinocactus have angular ridges on which the tufts of spines grow. Cereus has an angular, columnar, elongated stem. Phyllocactus and Rhipsalis have compressed leaf-like stems. Opuntia and Nopalea have flattened stems composed of a succession of flattened ovate shoots. The Cochineal insect lives on *Nopalea coccinellifera*.

Order 2. AIZOACEÆ (FICOIDEÆ). Flowers with a simple perianth and usually indefinite stamens, the more external of which are often transformed into petaloid staminodes: ovary multilocular.

Many species of Mesembryanthemum, natives of South Africa, are cultivated; in Aizoon the flowers are perigynous.

Cohort 3. **Passiflorales.** Flowers actinomorphic, epigynous, perigynous or hypogynous, pentamerous: stamens in one or two whorls, or indefinite; gynœcium syncarpous, ovary usually trimerous and unilocular: ovules numerous, on parietal placentæ.

Order 1. PASSIFLORACEÆ. Flowers pentamerous, perigynous; between corolla and andrœcium there is a disc consisting of a number of filamentous appendages: the andrœcium and the gynœcium are elevated upon an elongation of the axis: stamens five, often monadelphous, opposite to the sepals: leaves palmate. Climbing plants.

Several species of Passiflora, the Passion-Flower, from tropical America, are cultivated.

Order 2. PAPAYACEÆ. Flowers diclinous, hypogynous: stamens in two whorls: carpels five.

Carica Papaya, the Papaw, is cultivated in the tropics on account of its edible fruit: its latex is poisonous.

Order 3. BEGONIACEÆ. Affinity doubtful. Flowers diclinous; the male flowers have two dimerous petaloid perianth-whorls, and indefinite stamens crowded together; the female flowers are epigynous, the perianth consists of five petaloid leaves, the ovary is trilocular, with numerous anatropous ovules borne on axile placentæ: fruit a capsule: leaves often very large, usually oblique: inflorescence cymose, the male flowers being terminal on the first branches, the female terminal on the last.

Many species of Begonia, derived from the tropics, are cultivated as ornamental plants.

Order 4. CUCURBITACEÆ. Flowers diclinous or polygamous, actinomorphic: corolla gamopetalous, of five petals: stamens epipetalous, five, but two pairs cohere, so that there appear to be but three (Fig. 241, diagram); sometimes there is only one short one, with a large sinuous anther: ovary inferior, unilocular, or spuriously multilocular, with one or (more often) many parietal ovules: fruit baccate (a pepo or a succulent berry), often of great size, with a relatively thick and solid epicarp: seeds without endosperm. Herbs with scattered leaves, often climbers, the tendrils growing by the side of the leaves.

Cucurbita Pepo is the Pumpkin: the genus Cucumis has free stamens; *Cucumis sativa* is the Cucumber, and *Cucumis Melo* is the Melon: *Citrullus vulgaris* is the Water Melon. The genus Bryonia has a small white corolla; the loculi of the ovary are 2-seeded, and the fruit is a succulent berry; *B. dioica* is common in shrubberies and hedges.

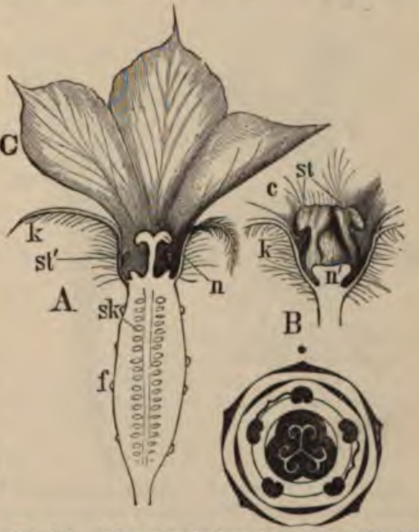


FIG 241.—*A* Longitudinal section of female flower of Cucumis: *f* ovary; *sk* ovules; *k* calyx; *C* corolla; *n* stigma; *st'* rudimentary stamens. *B* Longitudinal section of male flower: *st* stamens; *n'* rudimentary ovary; the corolla (*c*) is not all shown (somewhat mag.). Floral diagram of Cucurbita.

Cohort 4. **Myrtales.** Flowers usually actinomorphic, epigynous or perigynous, with commonly two whorls of stamens: gynœcium syncarpous, with usually a single style: leaves usually opposite.

Order 1. ONAGRACEÆ. Flowers usually tetramerous throughout, epigynous: ovary multilocular, with numerous ovules on axile placentæ: fruit a berry or a capsule; seed without endosperm. Calyx often petaloid, forming a long tube (Fig. 242 *A*, *r*).

Œnothera biennis, the Evening Primrose, occurs on river banks; the seed has not a tuft of hairs, and the flowers are yellow. Epilobium is the Willow Herb, of which many species are common; *E. angustifolium*, *hirsutum*, and *montanum* occur in fields, hedges, and ditches; the seeds have a tuft of long hairs; flowers red, fruit a septifragal capsule. *Circæa lutetiana* (Enchanter's Nightshade) has dimerous flowers $K2$, $C2$, $A2$, $G_{(2)}$; common in damp and shady spots. *Isnardia palustris* has no corolla; its fruit is a septicidal capsule. Fuchsia (Fig. 242 *A*), many species of which are cultivated as ornamental plants, is a native of South America; fruit a berry.

Order 2. LYTHRARIEÆ. Flowers perigynous, with two whorls of stamens: formula Kn, Cn, $An+n$, $G^{(2)}$, where $n=3—16$: ovary free in the hollow receptacle: an epicalyx formed by connate stipules is often present: seed without endosperm.

Lythrum Salicaria, the Loosestrife, occurs in bogs and ditches: formula $K6$, $C6$, $A6+6$, $G(\underline{2})$: the stamens of the two whorls are unequal in length, and the length of the style also varies; three forms of flowers are thus produced (trimorphism). Several species of Cuphea, with a posteriorly spurred calyx-tube, from Mexico, are cultivated.

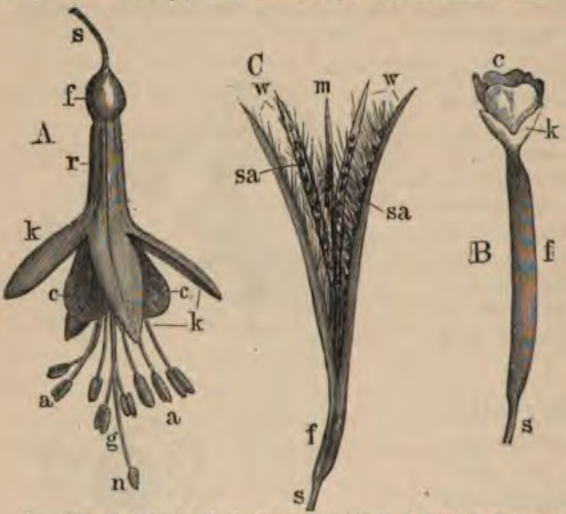


FIG. 242.—*A* Flower of Fuchsia: *s* pedicel; *f* inferior ovary; *k* sepals, connate at the base, forming a tube (*r*); *a* stamens; *g* style; *n* stigma. *B* Flower of *Epilobium hirsutum* (letters as before). *C* Fruit of Epilobium after dehiscence: *w* outer wall; *m* columella formed by the septa; *sa* seed with tufts of hairs (nat. size).

Order 3. MYRTACEÆ. Flowers 4- or 5-merous, epigynous: stamens often very numerous, or few and much branched (Fig. 243): seed without endosperm: leaves usually opposite, dotted with oil-glands.

Tribe 1. *Myrteæ*. Fruit a berry or a drupe; stamens indefinite.

Myrtus communis is the Myrtle of Southern Europe; Eugenia and Caryophyllus are also ornamental shrubs.

Tribe 2. *Leptospermeæ*. Fruit a capsule, dehiscing loculicidally from above downwards: stamens indefinite, in bundles which are opposite either to the sepals or to the petals (Fig. 243).

Callistemon, Melaleuca, Metrosideros, Calothamnus, and others, are ornamental plants: *Eucalyptus Globulus*, from Australia, is much planted in marshy districts, which it tends to dry up by its active transpiration.

Tribe 3. *Lecythideæ.* Fruit large, woody, dehiscing with a lid, or indehiscent; leaves scattered, without oil-glands: stamens indefinite.

Bertholletia excelsa grows in tropical America; its fruits are known as Brazil nuts.

Tribe 4. *Granateæ.* Fruit resembling a pome; leaves opposite, without oil-glands.

Punica granatum, the Pomegranate, grows in Southern Europe; flowers 5–8-merous; receptacle petaloid; stamens indefinite; in the ovary there are two whorls of loculi, an external superior of which the loculi are as numerous as and are opposite to the petals, and an internal inferior consisting of three loculi.

Order 4. RHIZOPHORACEÆ. Tropical trees with aërial roots, known as Mangroves: the seed often germinates in the fruit whilst it is still attached to the tree, and the primary root extends till it reaches the earth.

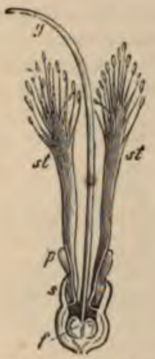


FIG. 243.—Longitudinal section of the flower of Calothamnus: *f* ovary; *s* calyx; *p* corolla; *st* branched stamens; *g* style. (After Sachs.)

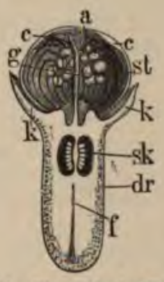


FIG. 244.—Flower-bud of Caryophyllus, the Clove, in longitudinal section: *f* the inferior ovary, with the oil-glands (*dr*); *sk* the ovules; *k* calyx; *c* corolla; *st* stamens; *a* anthers; *g* style (enlarged).

Cohort 5. **Rosales.** Flowers actinomorphic or zygomorphic, usually hermaphrodite, perigynous or epigynous: stamens rarely fewer in number than the petals or equal to them, generally indefinite in numerous whorls: gynœcium more or less completely apocarpous: ovules anatropous, suspended or erect; seed with or without endosperm.

Order 1. ROSACEÆ. Flowers actinomorphic, perigynous: gynœcium apocarpous: ovules 1 or few, anatropous; seeds without endosperm: leaves scattered, stipulate: the odd sepal is posterior.

Tribe 1. *Roseæ.* Carpels numerous, attached to the base and sides of the hollow receptacle, which is narrow above (Fig. 245 *C*); each contains a single suspended ovule, and when ripe, are achenes enclosed in the fleshy receptacle:

the sepals are frequently persistent at the top of it. Shrubs with imparipinnate leaves; the stipules are adnate to the petiole.

Many species of Rosa, the Rose, are wild, such as *R. arvensis, canina,* and *rubiginosa*, and many others are cultivated, as *R. centifolia, damascena, indica, rubifolia*, etc.

Tribe 2. *Spiræaceæ.* Carpels usually 5, each containing two or more suspended ovules: they are inserted upon the floor of the flat open receptacle: the calyx is persistent till the fruit is ripe.

Spiræa Ulmaria, Meadow-sweet, *Aruncus* and *Filipendula* (Dropwort) occur in woods and meadows, the fruit is a follicle; *Sp. sorbifolia, media, ulmifolia*, and other species, *Kerria japonica* (with achenes) and *Rhodotypus* (with drupes) are ornamental shrubs.

Tribe 3. *Amygdaleæ.* The single carpel, containing two suspended ovules, is inserted on the floor of the receptacle (Figs. 245 *A* and 246 *C*); the receptacle and the calyx fall off when the fruit is ripe: stamens usually in three whorls of 5 or 10; fruit a drupe (Fig. 162); only one seed is usually present.

The fruit of the genus Amygdalus has a furrowed coriaceous endocarp: *A. communis*, the Almond-tree, and *nana*, are trees of Southern Europe: *A. persica* is the Peach. The fruit of the genus Prunus has a smooth stony endocarp: *P. armeniaca* is the Apricot; *P. domestica* is the Wild Plum, it has an ovoid fruit and glabrous shoots; *P. insititia* is the Bullace, it has a globoid fruit and hirsute shoots; *P. Cerasus*, the Wild Cherry, has foliage-leaves at the base of its umbellate inflorescences; *P. Avium*, the Sweet Cherry (Gean), has only scales at the base of its inflorescences; *P. Padus*, the Bird-Cherry, has elongated racemose inflorescences; *P. Mahaleb*, the Damson, has fragrant bark; *P. laurocerasus*, the Cherry-Laurel, has evergreen leaves which somewhat resemble those of the true Laurel; *P. spinosa* is the Sloe or Blackthorn.

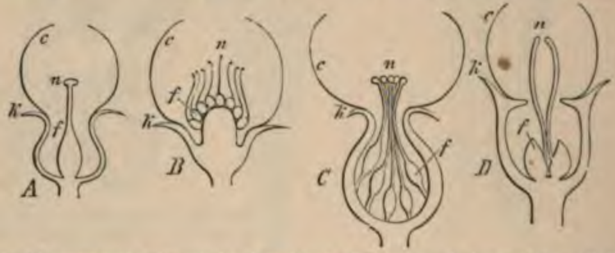


FIG. 245.—Diagrammatic longitudinal sections of flowers. *A* Amygdaleæ. *B* Dryadeæ *C* Roseæ. *D* Pomeæ: *k* calyx; *c* corolla; *f* ovaries; *n* stigmas.

Tribe 4. *Sanguisorbeæ.* Flowers often unisexual: ovaries few, often but one, monomerous, enclosed in the cavity of the receptacle which hardens as the seed ripens: ovules solitary, suspended.

The genus Alchemilla has tetramerous flowers destitute of a corolla; the stamens (4 or fewer) alternate with the sepals; an epicalyx is present: *A. vulgaris*, the Lady's Mantle, and *A. arvensis*, are common. The flowers of the genus Sanguisorba, the Great Burnet, have no corolla, the four stamens are opposite to the sepals, and they have no epicalyx; *S. officinalis* is common in meadows. The flowers of the genus Poterium, the Lesser Burnet, resemble those of the preceding, but the stamens are indefinite, and they are polygamous. The flower of Agrimonia is pentamerous; it has a corolla and indefinite stamens; the outer surface of the receptacle is beset with bristles.

Tribe 5. *Dryadeæ*. The ovaries, which are numerous, are inserted upon a prolongation of the axis into the cavity of the receptacle (Figs. 245 *B* and 246 *B*); each contains a single ovule. The calyx is usually surrounded by an epicalyx formed by the connate stipules of the sepals. The stamens are usually indefinite, each whorl consisting of as many or twice as many stamens as there are petals. These flowers are distinguished from those of the Ranunculaceæ, which they somewhat resemble, by the whorled arrangement of the stamens and by the presence of the hollow receptacle; for in Ranunculaceous flowers the stamens are arranged spirally and the sepals are quite free.

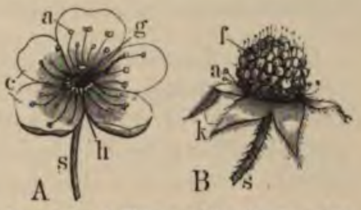


FIG. 246.—*A* Flower of the Cherry: *s* peduncle; *c* corolla; *a* stamens; *g* style, projecting out of the cavity of the receptacle. *B* Fruit of the Blackberry, *Rubus fruticosus*: *k* calyx; *f* fleshy ovaries.

Of the genus Potentilla, which has dry fruits and a dry receptacle, many species are common, such as *P. anserina*, the Silver-weed, *reptans*, *Tormentilla*, and others. Fragaria is the Strawberry; the receptacle becomes succulent as the fruit ripens and bears the small achenes on its surface; *F. vesca* and *elatior* are found in woods; *F. virginiana* and other North American species are cultivated. The flowers of the genus Rubus have no epicalyx and the fruits are succulent when ripe: *Rubus Idæus* is the Raspberry; its fruits separate from the dry receptacle when they are ripe: in *R. fruticosus*, the Blackberry, and *R. cæsius*, the Dewberry, the upper part of the receptacle separates together with the fruits when ripe. *Dryas octopetala* is a procumbent alpine shrub with an oval, long-tailed fruit (resembling that of *Clematis Vitalba*). *Geum urbanum* and *rivale* (Avens) occur in woods and damp fields; the long style is hooked.

Tribe 6. *Pomeæ*. Ovaries five or fewer, contained in the cavity of the receptacle, connate, and adnate to the wall of the receptacle (Fig. 245 *D*). The spurious fruit is surmounted by the calyx. The individual fruits either become hard and are like small drupes imbedded in the fleshy receptacle, or they have only a thin wall, so that they are more like capsules, and seem to be loculi of the whole fruit, as in the apple for instance, where the succulent portion is derived from the receptacle, and the core consists of the fruits enclosing the seeds, which are basal, generally two in each carpel. Stamens indefinite: no epicalyx. Shrubs or trees with deciduous stipules.

I. With stony fruits.

In the genus Cotoneaster, the fruits project above the receptacle: in Cratægus, the Hawthorn, they are completely enclosed; *C. oxyacantha*, the May, and *C. monogyna* are common; other species from the East and from North America are cultivated; Mespilus, the Medlar, has a large fruit which is surmounted by the five large sepals.

II. With coriaceous fruits.

Cydonia, the Quince, has numerous ovules on the ventral suture of each carpel; the outer layers of cells of the testa are mucilaginous. Pyrus has two basal ovules: *P. communis* and others are the Pear-trees; the loculi of the spurious fruit, seen in transverse section, are *rounded* towards the exterior; the fruit is not hollowed at the base: *P. Malus* and others are the Apple-trees; the fruit is hollowed at the base, and the loculi, seen in transverse section, are *pointed* towards the exterior. Sorbus resembles the preceding genus; *S. Aucuparia* is the Mountain Ash or Rowan-tree. Amelanchier, the Service-tree of Canada, has only one ovule in each loculus.

Order 2. LEGUMINOSÆ. Flowers usually medianly zygomorphic, perigynous, pentamerous, with calyx and corolla: stamens ten or more: ovary of a single anterior carpel: ovules borne on the ventral suture: fruit a legume or a lomentum: flowers always lateral: leaves nearly always compound.

Sub-order 1. PAPILIONACEÆ. Flowers zygomorphic, papilionaceous. The five sepals, one being anterior, are usually connate, forming a tube above the insertion of the corolla and the andrœcium: the five lobes are usually unequal and sometimes form two lips, the lower of three and the upper of two teeth: petals five, alternate with the sepals, imbricate, so that the anterior petals are overlapped by those behind them; the posterior petal is much enlarged, and is called the *vexillum* (Fig. 247 *A*, *fa*); the two lateral petals, which are much smaller, are termed the *alæ* (Fig. 247 *A*, *fl*); the two anterior petals are connate or sometimes simply apposed, and form a hollow boat-shaped body, the keel, or *carina* (Fig. 247 *A*, *s*). In a few cases the corolla is entirely or partially suppressed; thus in Amorpha, only the vexillum is present. The ten stamens are either connate, forming a tube, or the posterior stamen may be free, so that the tube consists of nine stamens, and is incomplete posteriorly (Fig. 247 *A*); rarely the stamens are all free: they mostly curve upwards, and diminish in length from in front backwards. The ovary, enclosed by the staminal tube, consists of a solitary anterior carpel; it is often divided into two chambers by a spurious longitudinal septum, or by transverse septa into several chambers. The fruit is usually a legume or a lomentum (Fig. 160 *A*), rarely one-seeded and indehiscent. The flowers are solitary and axillary, or in racemes. The leaves are only rarely entire, usually palmately or pinnately compound, with often large stipules (Fig. 8 *C*).

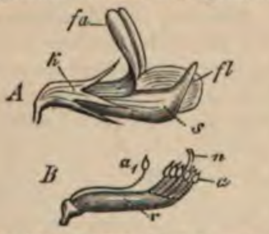


FIG. 247.—Flower of *Lotus corniculatus* (somewhat mag.). *A* With one ala removed; *k* calyx; *fa* vexillum; *fl* ala; *s* carina. *B* With the corolla removed; *r* tube formed by the stamens; a_1 the free stamen; *a* anther; *n* stigma.

Tribe 1. *Loteæ*. Leaves simple or compound: stamens diadelphous or monadelphous: legume unilocular, or bilocular in consequence of the formation of a spurious longitudinal dissepiment, usually dehiscent, many-seeded: cotyledons leafy, epigæal.

In Ulex the Whin, Gorse or Furze, Genista the Green-weed, Cytisus (Sarothamnus) the Broom, Ononis the Rest-harrow, and Lupinus, the stamens are monadelphous; in Genista the leaves are simple; in Sarothamnus and Ononis the leaves are ternate; in Ulex the leaves are ternate in seedlings, but in mature plants they are scaly or spinous; in Lupinus the leaves are palmately compound. *Cytisus Laburnum* is a well-known flowering tree.

In Medicago, Melilotus, Trifolium, and Lotus, the stamens are diadelphous and the leaves ternate. Trifolium is the Clover: the stamens are partially adnate to the corolla; the withered corolla persists and encloses the small legume: flowers in capitula; *T. pratense*, the Red Clover, *T. repens*, the White Clover, and *hybridum*, which are common in meadows, and *T. incarnatum*, from the East, are cultivated. *Lotus corniculatus*, the Bird's-foot Trefoil, with a beaked carina and spirally-wound legume, is common in meadows. Medicago has usually a spirally-wound legume, and a deciduous corolla; *M. falcata* and *lupulina* are common; *M. sativa*, Lucerne, is cultivated. Melilotus has a globular legume; *M. alba* and *officinalis* are common on the banks of the streams. Trigonella.

In Anthyllis, the Kidney-Vetch, the stamens are monadelphous, and the leaves imparipinnate. *Anthyllis Vulneraria*, Ladies' Fingers, is common in dry pastures.

In the remaining genera the leaves are imparipinnate and the stamens diadelphous. *Indigofera tinctoria*, in the East Indies, produces Indigo. Glycyrrhiza is the Liquorice. Colutea, the Bladder Senna, has a swollen fruit; *C. arborescens* and various species of Caragana are cultivated as ornamental plants. *Robinia Pseudacacia*, the false Acacia, is a native of North America, but it has become naturalized. *Amorpha fruticosa* is a common shrub, from North America. Astragalus has a legume with a spurious longitudinal dissepiment: very many species of it occur, especially in the East.

Tribe 2. *Hedysareæ*. Leaves imparipinnate; stamens diadelphous: fruit a lomentum, with transverse septa, dividing into segments. Cotyledons leafy, epigæal.

Hippocrepis and Coronilla are common in meadows; *Onobrychis sativa*, the Sainfoin, is cultivated. *Arachis hypogæa*, the Earth-Almond or Ground Nut of tropical America, ripens its fruits in the earth.

Tribe 3. *Vicieæ*. Stamens diadelphous: legume unilocular; cotyledons hypogæal; leaves paripinnate and usually cirrhose.

Vicia sativa, the Vetch, and *V. Faba*, the Bean, are cultivated: other species occur wild. *Pisum sativum* and *arvense*, the Pea, are cultivated. *Ervum lens*, the Lentil, belongs to Southern Europe. Various species of Lathyrus and Orobus occur wild in woods; *L. odoratus* and others are cultivated.

Tribe 4. *Phaseoleæ*. Stamens diadelphous: legume unilocular; cotyledons usually epigæal, but not leafy: leaves usually imparipinnate, frequently ternate.

Phaseolus vulgaris, the French Bean, and *P. multiflorus*, the Scarlet Runner, are cultivated. *Wistaria chinensis* is an ornamental climber. Physostigma is the Calabar Bean.

Tribe 5. *Dalbergieæ*. Stamens mono- or diadelphous: legume indehiscent; cotyledons fleshy.

Pterocarpus. *Dipterix odorata*, the Tonka Bean of South America, contains coumarin in the seed.

Tribe 6. *Sophoreæ.* Stamens all free. *Sophora japonica* and *Cladrastis lutea* are ornamental plants. Myroxylon.

Sub-order 2. CÆSALPINIEÆ. Flower zygomorphic, but not papilionaceous (Fig. 248); petals imbricate, so that the posterior petal is overlapped by those anterior to it; stamens ten or less, free, more rarely connate: the legume is frequently divided by transverse septa, and is indehiscent: flowers in panicles or racemes.

Gleditschia triacanthos and other species are cultivated for ornament. *Cercis siliquastrum*, the Judas-tree, has rounded leaves. The wood of *Cæsalpinia brasiliensis* is known as Pernambuco or Brazil wood.

Sub-order 3. MIMOSEÆ. Flowers actinomorphic, with valvate æstivation: stamens ten, rarely fewer, frequently very numerous, free (Fig. 249), usually much longer than the perianth: legume sometimes divided by transverse septa. The flowers usually grouped in spikes or capitula.

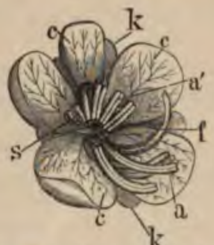


FIG. 248.—Flower of a Cassia: *k* calyx; *c* corolla; *a* stamens; *a'* the central shorter ones; *f* ovary.

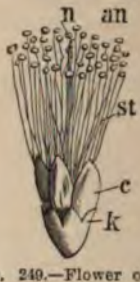


FIG. 249.—Flower of an Acacia (mag.): *k* calyx; *c* corolla; *st* stamens, with (*an*) anthers; *n* stigma.

Mimosa pudica, the Sensitive Plant, has irritable leaves. Species of Acacia are numerous in Africa, Asia, and Australia. In the Australian species the leaves are represented by flattened petioles (phyllodes) which are extended in the median plane.

Order 3. CRASSULACEÆ. Formula Kn, Cn, $An\ [\,+\ n\,]$, Gn, where $n = 3$—30: flowers perigynous, with two (rarely one) whorls of stamens: gynœcium apocarpous, carpels opposite to the petals, with a scale (disc) behind the carpels: ovules numerous, marginal: fruit a follicle: seed with endosperm: inflorescence usually cymose. Plants with entire fleshy leaves, arranged spirally, often in rosettes.

The genus Sedum has usually pentamerous flowers; *Sedum acre*, the Stonecrop, is common on walls and rocks: *S. maximum* and others are common. The genus Sempervivum has at least 6-merous flowers; *S. tectorum*, the House-leek, and other species, Echeveria, Crassula, etc., are frequently cultivated.

Order 4. SAXIFRAGACEÆ. Flowers usually 4–5-merous, epigynous or perigynous: stamens usually in two whorls: carpels less numerous, usually connate below and free above: seed containing endosperm.

Tribe 1. *Saxifrageæ.* Flowers perigynous or epigynous, actinomorphic or zygomorphic: petals with imbricate æstivation: two whorls of stamens, or only one (opposite to the sepals): carpels usually two, diverging above: inflorescence of racemose cymes: fruit a capsule: leaves alternate.

The genus Saxifraga has a bilocular ovary, but the flower is otherwise pentamerous; the receptacle invests the lower connate portion of the ovary. Many species occur in mountainous districts, and in several of them there is a deposit of carbonate of lime on the margins of the leaves; only a few species, such as *S. tridactylites* and *granulata*, occur in the plains; *S. sarmentosa* is frequently cultivated indoors. The genus Bergenia has a free ovary (Fig. 250); *B. bifolia*, from Siberia, is an ornamental plant. The genus Chrysosplenium has a tetramerous flower destitute of a corolla; they are small plants, somewhat resembling a Euphorbia, occurring in damp places.

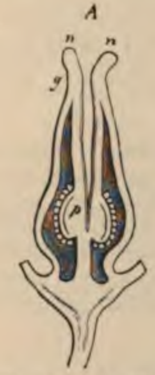


FIG. 250.—Longitudinal section of the ovary of Bergenia: *g* style; *n* stigmas; *p* placentæ (mag.) (After Sachs.)

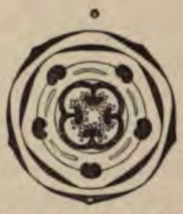


FIG. 251.—Floral diagram of Parnassia.

Tribe 2. *Parnassieæ.* Flowers perigynous, actinomorphic; the five stamens opposite to the petals are transformed into glandular staminodes: petals with imbricate æstivation: ovary 4-locular: ovules numerous: fruit a loculicidal capsule: leaves alternate.

Parnassia palustris has a whorl of radical leaves, and terminal and lateral peduncles, each bearing a single flower and adnate to a bracteole: it is frequently found in damp localities.

Tribe 3. *Hydrangeæ.* Flowers epigynous, actinomorphic, with two whorls of stamens: petals with valvate æstivation: leaves opposite.

Hydrangea hortensis is a well-known garden plant. The inflorescence is an umbellate panicle, the marginal flowers of which (in cultivated plants all of them) are tetramerous; they have a very much enlarged calyx, and only the whorl of stamens opposite to the sepals; they are sterile.

Tribe 4. *Philadelpheæ.* Flowers epigynous, actinomorphic, 4–5-merous:

stamens in two whorls, or indefinite: petals with various æstivation: leaves opposite: fruit a capsule.

Philadelphus coronarius (called Syringa or Mock Orange) has sweetly-scented flowers. *Deutzia scabra, crenata*, and others are cultivated.

Tribe 5. *Ribesiaceæ*. Flowers epigynous, actinomorphic, pentamerous: stamens opposite to the sepals: carpels two: fruit a berry: leaves scattered: palmate: inflorescence racemose. Shrubs.

Several species of Ribes, the Currant, are cultivated; *R. rubrum* is the Red Currant, *R. nigrum* the Black Currant, *R. Grossularia* the Gooseberry: the spines of the last species are developed from the pulvinus.

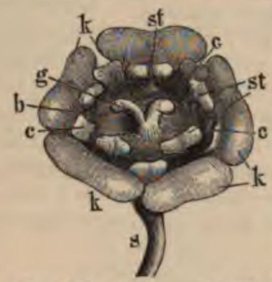


FIG. 252.—Flower of Ribes (mag.): *s* pedicel; *k* calyx; *c* corolla; *st* stamens; *b* disc; *g* styles.

Order 5. DROSERACEÆ. Floral formula $K5, C5, A5, G^{\underline{(3)}}$ or $^{\underline{(5)}}$: flowers actinomorphic, perigynous or hypogynous: ovary unilocular, ovules borne generally on parietal placentæ, but they are sometimes basal. Herbs: leaves exstipulate, with glandular, hair-like appendages which serve to capture insects (see Fig. 72).

Drosera has a scorpioid inflorescence borne on a scape without bracteoles; the leaves are radical and are fringed with glandular appendages, each of which is traversed by a fibro-vascular bundle. *D. rotundifolia* and *intermedia*, the Sun-dews, are found on wet heaths. *Aldrovanda vesiculosa* is a floating water-plant of Southern Europe; its whorled leaves fold up when stimulated; flowers solitary, axillary. *Dionæa muscipula*, Venus' Fly-trap, occurs in North America; it has leaves which likewise fold together when touched; flowers with 10–20 stamens and basal ovules.

Order 6. HAMAMELIDEÆ. Flowers frequently diclinous and apetalous, perigynous or nearly epigynous; ovary usually bilocular: leaves stipulate.

Hamamelis virginica, the Witch-Hazel, is an ornamental shrub from North America, the leaves of which somewhat resemble those of the Hazel.

Order 7. HALORAGIDEÆ. Flower perigynous or epigynous, usually tetramerous throughout; stamens in two whorls: sometimes the corolla or the whorl of stamens opposite to the petals is wanting: seed containing endosperm.

Trapa natans, the Water-Chestnut, a not very common water-plant of central Europe, has a stem bearing a rosette of leaves which float on the surface of the water; in the axils of these leaves the flowers are borne singly: their formula is $K4, C4, A4, G\,(^{2})$, and they are perigynous: the fruit is indehiscent, and the sepals remain adherent to it in the form of four horns.

Myriophyllum verticillatum and *spicatum*, the Water-Milfoils, are aquatic plants with finely divided leaves and small flowers borne above the water in terminal spikes.

Order 8. HIPPURIDEÆ. Flowers sometimes unisexual, borne singly in the axils of the whorled leaves: the calyx is indicated by a projecting rim on the ovary, and it invests also a single anterior stamen: petals 0; stamen 1, epigynous: the monomerous ovary contains a single suspended anatropous ovule.

Hippuris vulgaris, the Mare's tail, grows in water and in damp places: the stem projects out of the water.

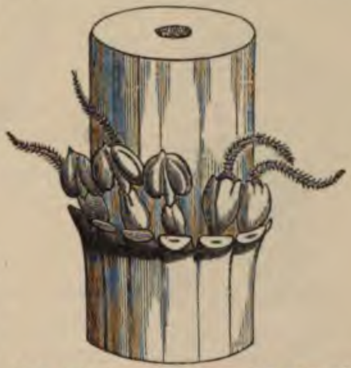


FIG. 253.—Part of a flowering stem of *Hippuris vulgaris*. The leaves are cut away. (After Sachs.)

Order 9. CALLITRICHINEÆ. Aquatic plants, with decussate, linear or ovate leaves, in the axils of which stand the solitary diclinous flowers which are destitute of a perianth; the male flowers consist of a single stamen, the female of a bilocular, spuriously quadrilocular, ovary, with four suspended ovules the micropyles of which are directed outwards.

Callitriche verna and others are either submerged or they creep on muddy banks.

SERIES II. DISCIFLORÆ.

Sepals free or coherent: petals in a single whorl: stamens usually definite, and hypogynous: a disc is usually present: gynœcium syncarpous or apocarpous.

Cohort 1. **Sapindales.** Flowers often unisexual: the insertion of the stamens is various: gynœcium usually syncarpous. Usually trees.

Order 1. SAPINDACEÆ. Flowers usually obliquely zygomorphic, in that the two petals of one side are larger and of somewhat different form to the three others; of these, one, which lies in the plane of symmetry, is sometimes wanting: three stamens are usually suppressed, so that the number is reduced to seven; they are inserted within the disc: the ovary is trilocular; ovules two in each loculus: seeds without endosperm.

Æsculus has opposite, palmately compound, exstipulate leaves: the flowers are in terminal scorpioid racemes: the fruit has a loculicidal dehiscence; *Æ. Hippocastanum* is the Horse-Chestnut, derived from Asia. *Æ. carnea*, *Æ. Pavia*, and other species are frequently cultivated. A great number of genera and species grow in warm climates; they have generally scattered pinnate leaves. The fleshy fruit of *Sapindus Saponaria* makes a lather with water like soap.

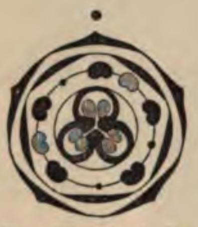


FIG. 254.—Floral diagram of Æsculus.

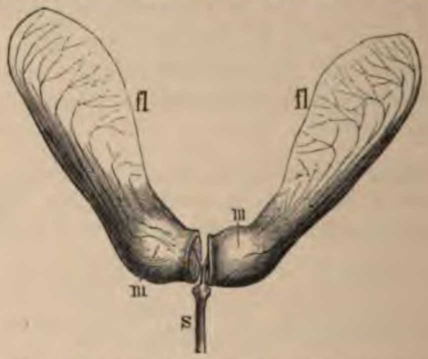


FIG. 255.—Fruit of *A. platanoides*, dividing into two mericarps *m*; *s* pedicel; *fl* wings (nat. size).

Order 2. ACERINEÆ. Flowers usually actinomorphic: stamens eight, in consequence of the suppression of the two median ones, variously inserted: ovary bilocular; ovules two in each loculus; when ripe the fruit splits into two one-seeded winged mericarps (samaras) (Fig. 255); leaves opposite, palmately lobed, exstipulate: flowers in terminal racemes, sometimes in corymbs, with an apical flower: seeds without endosperm.

The principal species of Acer, the Maple, are *A. pseudoplatanus*, the Sycamore, having leaves with crenate margins, flowers in elongated pendulous racemes, blooming after the unfolding of the leaves, and parallel-winged fruits; *A. platanoides*, having leaves with serrate margins, flowers in short erect racemes blooming before the unfolding of the leaves, and fruits with widely diverging wings (even more than in Fig. 255); *A. campestre*, the common Maple, which is sometimes shrubby, with a trilobate leaf, short erect racemes of flowers which bloom after the unfolding of the leaves, and fruits with wings which are diametrically opposite. Some North American species are often cultivated, such as *A. rubrum*, with five stamens opposite to the sepals; *A. dasycarpum*, with the same number and position of the stamens, without any corolla, and having diœcious flowers; *A. Negundo*, with pinnate leaves, and diœcious flowers like those of the preceding species. Sugar is prepared from the sap of *A. nigrum* and *dasycarpum* especially.

Order 3. TEREBINTHACEÆ (ANACARDIACEÆ). Flowers usually actinomorphic, and often diclinous: stamens usually inserted on the disc, but disc sometimes absent: gynœcium of but few carpels; sometimes one only is developed, the others being represented by two or more stigmas: resin-ducts present: seeds without endosperm.

Various species of Rhus are cultivated as ornamental plants; in *Rhus cotinus* many of the flowers are abortive, and the hairy peduncles become much elongated; *R. coriaria* (Southern Europe) is used in tanning. *Pistacia vera*, in Southern Europe, bears edible fruits; in its flower the petals and the stamens which are opposite to them are suppressed.

Order 4. STAPHYLEACEÆ. Flowers actinomorphic, pentamerous: stamens external to the disc: ovules numerous: leaves decussate, pinnate, stipulate: seeds with small endosperm.

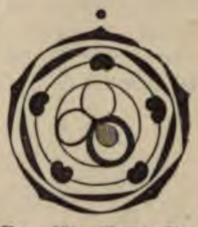


FIG. 256.—Floral diagram of Rhus.

Staphylea pinnata is grown in gardens.

Cohort 2. **Celastrales.** Flowers actinomorphic, 4-5-merous; one whorl only of stamens, which either alternates with or is opposite to the petals, is usually present: disc usually within, sometimes external to, the andrœcium: ovules usually erect: the seed nearly always contains endosperm. Trees or shrubs.

Order 1. CELASTRINEÆ. Formula, $Kn, Cn, An + 0, G$ (n) or less, n = 4 or 5: sepals imbricate: stamens and carpels inserted on a flattened disc; stamens alternate with the petals: usually two ovules in each loculus of the ovary: leaves scattered, entire, stipulate.

In the genus Euonymus, the Spindle-tree, the loculicidal capsule is invested by an orange-coloured arillus; *E. europæus* occurs both cultivated and wild.

Order 2. RHAMNEÆ. Formula $Kn, Cn, \mid A0 + n, G^{\underline{(2\text{-}4)}}$; n = 4 or 5: calyx usually gamosepalous, valvate: petals usually small and often hood-shaped (Fig. 257 *c*), enclosing the stamens which are opposite to them: flowers sometimes diclinous; usually a single ovule in each loculus of the ovary, which is invested by a disc; leaves usually scattered, entire, stipulate: fruit a drupe or a capsule.

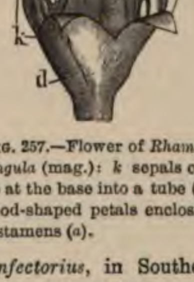


FIG. 257.—Flower of *Rhamnus Frangula* (mag.): *k* sepals connate at the base into a tube (*d*); *c* hood-shaped petals enclosing the stamens (*a*).

Rhamnus cathartica, the Buckthorn, has opposite leaves and thorny twigs: the berries of *R. infectorius*, in Southern Europe, yield a green or yellow dye: *R. Frangula* has scattered leaves; its wood produces a particularly light charcoal.

Order 3. AMPELIDEÆ. Formula same as in Rhamneæ: sepals small; the corolla is often thrown off before it opens (Fig. 258 *A*, *c*): a glandular disc between the andrœcium and the gynœcium: ovules one or two in each loculus: fruit baccate. Climbing plants, with palmate exstipulate or stipulate leaves.

Vitis vinifera, the Grape-Vine, probably derived from the East, is cultivated in endless varieties; other species, such as *V. vulpina* and *Labrusca*, as also *Ampelopsis hederacea*, the Virginia Creeper, are also frequently cultivated. The tendrils of the Vine (Fig. 15 *A*) are branches bearing scaly leaves in the axils of which other branches arise: their peculiar position opposite to the foliage-leaves may be explained as follows: the ordinary shoots are sympodia, and each tendril is the terminal segment of a member of the sympodium; the following member is a shoot springing from the axil of the foliage-leaf which is opposite to the tendril. Every third leaf has no tendril opposite to it, that is to say, the members of the sympodium bear alternately one or two leaves. The inflorescences occupy the same positions as the tendrils. Each leaf has also a bud in its axil, which either remains undeveloped or gives rise to a dwarf-shoot: from the axil of its cataphyllary leaf an ordinary shoot is developed.

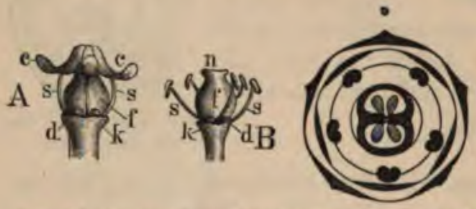


FIG. 258.—Flower of *Vitis vinifera*, and diagram. *A* At the moment of opening. *B* Open; *k* calyx; *c* corolla; *d* glands; *s* stamens; *f* ovary; *n* stigma (slightly mag.).

Cohort 3. **Olacales.** Flowers sometimes unisexual, 4–5-(rarely 6-) merous, formula same as Celastrineæ: disc various or wanting.

Order 1. ILICINEÆ (AQUIFOLIACEÆ). Disc wanting: one or two suspended ovules in each loculus of the ovary: stamens free, or adnate to the petals: petals often connate at the base: leaves scattered, exstipulate.

Ilex aquifolium, the Holly, with its coriaceous, spinous, evergreen leaves, is common in plantations and woods: fruit a berry. The leaves known in commerce as Paraguay tea are derived from *I. Paraguayensis* in South America.

Order 2. EMPETREÆ. Disc wanting: ovules solitary, ascending: flowers diœcious, with three sepals, three petals, three stamens, and a 6–9-locular ovary: fruit of 6–9 drupes. They are shrubs resembling Heaths in appearance.

Empetrum nigrum is a small shrub occurring in the north of Europe and in the Alps.

Cohort 4. **Geraniales.** Flowers usually pentamerous throughout; the carpels are opposite to the petals: ovary usually 5-locular, with 1 or 2 suspended ovules; the micropyle is directed inwards: disc various or wanting: formula $K5$, $C5$, $A5+5 \mid G^{\textcircled{5}}$.

Order 1. GERANIACEÆ. Disc glandular: flowers usually actinomorphic: two ovules in each loculus; the ovary is prolonged into a beak (carpophore) (Fig. 259 *A*, *a*); the fruit is septicidal from below upwards, the separate carpels (cocci) rolling up (Fig. 259 *B*). Seed devoid of endosperm. Herbs; leaves simple, stipulate.

Geranium pratense, *sylvaticum*, *sanguineum*, and *columbinum*, the Crane's-bills, are wild in England; *G. Robertianum*, Herb-Robert, is universally distributed. Erodium, the Stork's-bill, has the 5 stamens which are opposite to the petals transformed into staminodes; *E. cicutarium* is common in waste places. Pelargonium, in many varieties, is a well-known garden plant: the flowers are zygomorphic, and the posterior sepal is provided with a spur which adheres to the pedicel.

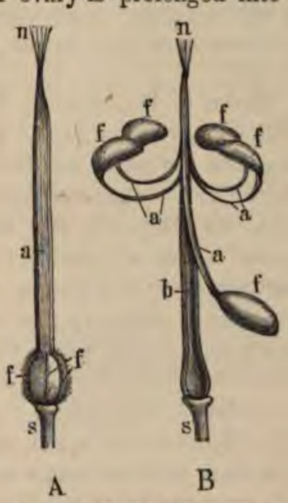


FIG. 259.—Fruit of Geranium. *A* Before, *B* after dehiscence; *s* pedicel; *f* loculi of the ovary; *a* the beak; *n* stigma; *b* column of the septa (mag.).

Order 2. LINEÆ. Disc 0: formula $K5$, $C5$, $A5 + \dagger 5$, $\mid (G^{\underline{\textcircled{5}}})$: flowers actinomorphic, rarely all the whorls are tetramerous: the whorl of stamens opposite to the petals is replaced by staminodia: each loculus of the ovary contains two ovules, and is often divided into two by a more or less complete false dissepiment: seeds usually contain endosperm: capsule septicidal. Herbs or shrubs; leaves simple, entire, with or without stipules.

Linum usitatissimum is the Flax: the strong bast-fibres are used in weaving linen; the seeds contain oil; the walls of the outer cells of the testa are mucilaginous.

Order 3. ERYTHROXYLEÆ. Flowers actinomorphic: petals five, with a ligular appendage: stamens ten, connate at the base by means of a disc and forming a tube: ovary 2-3-locular, with one suspended anatropous ovule in each loculus: seed with endosperm.

The wood of most of the species contains a red dye. The leaves of *Erythroxylon Coca* is chewed by the Peruvians as a stimulant.

Order 4. OXALIDEÆ. Disc 0: flowers actinomorphic; formula $K5$, $C5$, $A5+5$, | $G^{\underline{(5)}}$; stamens ten, connate at the base; those which are opposite to the sepals are the longest: ovules numerous; fruit a capsule or more rarely a berry: seed containing endosperm. Herbs, with compound, generally exstipulate leaves (Fig. 71).

Oxalis Acetosella, the Wood-sorrel, is frequent in woods; it contains much potassium oxalate. The tuberous roots or underground stems of some American species as *O. esculenta*, *crenata*, and *Deppei* contain much mucilage and are used as food.

Order 5. BALSAMINEÆ. Disc 0: flowers zygomorphic; formula $K5$, $C5$, $A5+0$ | $G^{\underline{(5)}}$: the posterior sepal is spurred, and the two anterior are small or absent: the anterior petal is large; ovary 5-locular; ovules numerous; the fruit is loculicidal, the valves separate elastically and roll upwards, so that the seeds are projected to some distance. Herbs, with simple exstipulate leaves: seeds without endosperm.

Impatiens Noli-me-tangere, the yellow Wild Balsam, occurs in damp and shady spots; the ripe fruit flies open with violence at a touch. *Impatiens balsamina*, an Indian species, is cultivated.

Order 6. TROPÆOLEÆ. Disc 0: flowers zygomorphic; formula $K5$, $C5$, $A4+4$, $G^{\underline{(3)}}$: the posterior sepal is prolonged into a spur; the three inferior petals are clawed and ciliate: the two median stamens, one belonging to each whorl, are suppressed: one ovule in each of the three loculi of the ovary: seeds without endosperm. Herbs, leaves exstipulate.

Tropæolum majus and *minus*, known as Nasturtium, are universally cultivated.

Order 7. ZYGOPHYLLEÆ. Disc fleshy: flowers actinomorphic, 5 or 4-merous. Herbs or shrubs with decussate, generally imparipinnate, stipulate leaves: seeds with endosperm.

Lignum Vitæ is the wood of *Guiacum officinale* (West Indies).

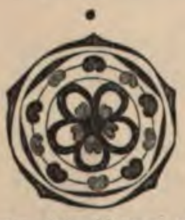


FIG. 260.—Diagram of the flower of Dictamnus.

Order 8. RUTACEÆ. Disc usually annular: flowers usually actinomorphic: gynœcium sometimes partially apocarpous, but the styles are usually connate: seeds with or without endosperm. There are numerous oil-glands on the leaves and stems.

Sub-order 1. RUTEÆ. The placentæ project into the loculi of the ovary; each bears 3 or more ovules: fruit a loculicidal capsule: seed with endosperm. *Ruta graveolens*, the Rue, has pentamerous terminal flowers, and tetramerous lateral flowers. *Dictamnus Fraxinella* has a zygomorphic flower.

Sub-order 2. Diosmeæ. Ovules 2 in each loculus: leaves simple: seeds without endosperm.

Barosma, Agathosma, Empleurum.

Sub-order 3. Xanthoxyleæ. Flowers usually diœcious and polygamous: endosperm usually present.

Xanthoxylum fraxincum, from North America, is a shrub which is sometimes cultivated.

Sub-order 4. Toddalieæ. Gynœcium syncarpous: fruit indehiscent, winged, dry or succulent: seeds with endosperm.

Ptelea trifoliata is a North American shrub with white flowers.

Sub-order 5. Aurantieæ. Gynœcium syncarpous: calyx gamosepalous: seeds without endosperm.

The genus Citrus has an indefinite number of bundles of connate stamens (polyadelphous) (Fig. 261 *A*), produced by the branching of the five stamens which are opposite to the sepals: the carpels are usually more numerous than the petals, and during ripening they become filled with a succulent tissue derived form their walls; the various parts of the flower and the fruit contain much ethereal oil: the leaves, which are typically pinnate, are reduced to their terminal leaflet, which is articulated to the winged petiole (Fig. 11 *G*).

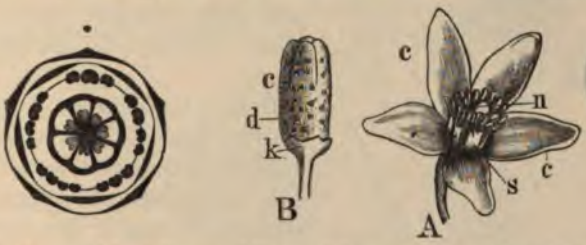


Fig. 261.—Flower and floral diagram of Citrus. *A* Open; *c* corolla; *s* the partially connate stamens; *n* the stigma. *B* Bud; *k* calyx; *c* corolla; *d* oil-glands.

Citrus medica, and *Limonum*, are Lemons: *Citrus vulgaris* or *Aurantium* is the Orange, derived originally from tropical Asia.

Order 9. Meliaceæ. Disc various: stamens monadelphous; the filaments have stipulate appendages; no oil-glands.

Mahogany is the wood of *Swietenia Mahagoni* (America). The wood of species of Cedrela is often erroneously termed "cedar-wood."

Order 10. Simarubeæ. Disc conspicuous: flowers actinomorphic, sometimes diclinous: stamens often more numerous than the petals: gynœcium sometimes apocarpous: ovule usually solitary in each loculus: there are no oil-glands in the leaves, but the cortex and wood contain a bitter substance.

Ailanthus glandulosa, from China, is a tree with multijugate pinnate leaves and a winged indehiscent fruit; it is often cultivated.

Order 11. BURSERACEÆ. Disc usually annular: flowers actinomorphic: gynœcium syncarpous; ovary with two ovules in each loculus: there are resin-passages in the bast.

Boswellia serrata (East Africa) yields Olibanum, a gum-resin; *Balsamodendron Myrrha* yields the gum-resin Myrrh (Arabia).

SERIES III. THALAMIFLORÆ.

Sepals usually free: petals often indefinite: stamens hypogynous, often indefinite: gynœcium apocarpous or syncarpous.

Cohort 1. **Malvales.** Flowers cyclic, generally pentamerous, actinomorphic: calyx often gamosepalous, with valvate æstivation, corolla with usually contorted æstivation; stamens originally in two whorls, generally branched and often connate: carpels five, often forming a multilocular ovary.

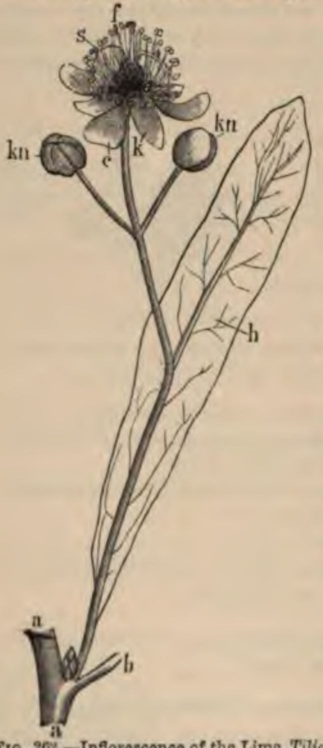


FIG. 262.—Inflorescence of the Lime, *Tilia grandifolia*: *a* branch; *b* petiole and axillary bud. Attached to the peduncle is the bract (*h*): *k* calyx; *c* corolla; *s* stamens; *f* ovary; *kn* flower-bud (nat. size).

Order 1. TILIACEÆ. Sepals usually free. In the indigenous species the staminal whorl opposite to the sepals is suppressed; stamens branched, the separate branches of the filament free or connate only at the base, opposite to the petals: anthers 2-locular, opening by pores or valves: ovary 5-locular, each loculus containing two ovules; but the fruit is generally only one-seeded. Mostly trees or shrubs: leaves alternate, stipulate.

The only indigenous genus is Tilia, the Lime-tree. It has oblique leaves with deciduous stipules; the annual shoots have not a terminal bud. The inflorescence is cymose, few-flowered; the peduncle is adnate to the leafy bract; this is brought about in the following manner: in the axil of the leaves there is usually a bud, together with an inflorescence (Fig. 262); the bract (Fig. 262 *h*) and the bud-scale which is opposite to it are the first two leaves of the axillary shoot which is terminated by the inflorescence, the peduncle of which is adnate to the bract for some distance: the bud is a winter-bud developed in the axil of the above-mentioned bud-scale. The inflorescence itself terminates in a flower; other flowers are borne in the axils of its two bracteoles, and other flowers again may be developed in the axils of their bracteoles, and so on. *T. grandifolia*, the Large-leaved Lime, has a few-flowered inflorescence, and leaves which are bright green and downy on the under surface: *T. parvifolia* has an inflorescence which consists of a large number of flowers, and has leaves which are bluish-green and pubescent with red hairs on the under surface. *T. intermedia* is the common Lime. In the American species the internal branches of the stamens are staminodia. Corchorus, in the East Indies, yields Jute, which consists of the bast-fibres.

Order 2. STERCULIACEÆ. Calyx gamosepalous: the stamens which are opposite to the petals are usually doubled or branched; those which are opposite to the sepals are staminodes or they are suppressed: anthers 2-locular: the corolla is sometimes wanting.

Theobromo Cacao is a tree of tropical America, the seeds of which contain a nitrogenous substance, *Theobromine*, and a fixed oil; from them Chocolate is prepared.

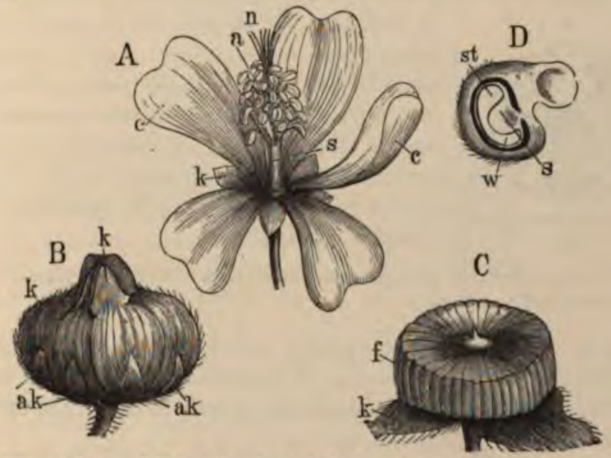


FIG. 263.—*A* Flower of *Malva Alcea* (nat. size): *k* calyx; *c* corolla; *s* connate stamens, with the anthers (*a*); *n* stigmas. *B* Fruit of *Althæa rosea* inclosed in (*k*) the calyx: *ak* epicalyx. *C* The same after the removal of the calyx. *D* A single loculus of the same in longitudinal section: *s* seed; *w* radicle; *st* cotyledon of the embryo (mag.).

Order 3. MALVACEÆ. Calyx usually gamosepalous, frequently invested by an epicalyx; the corolla is adnate at the base to the andrœcium: the andrœcium is a long tube (Fig. 263 *A s*) consisting of five branched stamens which are opposite to the sepals; each filament bears only half an anther, which is regarded as a unilocular anther (Fig. 263 *A a*): ovary multilocular, splitting into cocci (Fig.

263 *C f*), with usually one ovule in each coccus (Fig. 263 *D s*) Under-shrubs or herbs: leaves stipulate and generally palmately veined.

Malva, the Mallow, has an epicalyx of three bracteoles, Hibiscus has one of many bracteoles, and Althæa, the Marsh-mallow, has one of 6–9 bracteoles; *Althæa rosea* is the Hollyhock; several species of Malva are indigenous, *M. sylvestris*, *rotundifolia*, and *moschata*. *Gossypium herbaceum* in Egypt, *G. arboreum* and *religiosum* in the East Indies, and *G. peruvianum* and *hirsutum* in America yield Cotton, which consists of the long hairs on the testa.

Cohort 2. **Guttiferales.** Flowers cyclic, actinomorphic, and generally pentamerous: sepals usually free, with imbricate æstivation: stamens usually indefinite in consequence of branching: gynœcium syncarpous, ovary uni- or multilocular.

Order 1. HYPERICINEÆ. Formula, $K5$, $C5$, $A0+5\infty$, $G^{(5)}$ or $A0+3\infty$, $G^{(3)}$. Sepals sometimes united at the base: stamens five, branched, and therefore polyadelphous, superposed on the petals in consequence of the suppression of an outer whorl of stamens which is indicated by staminodes in some foreign genera: ovary uni- or multilocular or many-chambered: capsule septicidal: ovules numerous, anatropous; placentæ parietal or axile: seed devoid of endosperm. Herbs or under-shrubs with decussate entire leaves, which are dotted over with translucent oil-glands; exstipulate.

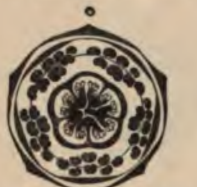


FIG. 264.—Diagram of Hypericum.

Hypericum perforatum, *hirsutum*, and *humifusum* (St. John's Worts) occur wild in woods and meadows.

Order 2. ELATINEÆ. Water-plants with entire leaves, opposite or in whorls: flowers actinomorphic, 4–6-merous; formula Kn, Cn, $An+n$, $G^{(n)}$, solitary, without bracteoles, borne in the axils of the foliage-leaves.

E. hexandra and *Hydropiper* (Waterworts) occur, but not commonly, in England.

Order 3. TERNSTRŒMIACEÆ. Perianth spiral; the calyx is not clearly distinguishable from the numerous bracts; stamens indefinite: ovary multilocular. Trees or shrubs with scattered, generally coriaceous, entire leaves, without stipules.

Camellia japonica is a favourite ornamental shrub: *Thea chinensis*, of which the dried leaves are tea; black and green tea are varieties resulting only from the mode of drying the leaf.

Order 4. CLUSIACEÆ (GUTTIFERÆ). Trees or shrubs with diclinous flowers.

Order 5. DIPTEROCARPEÆ. Trees; leaves usually stipulate; the gamosepalous calyx enlarges very much during the ripening of the fruit.

Dryobalanops Camphora, a native of Sumatra, yields the Borneo Camphor.

Cohort 3. **Caryophyllinæ.** Flowers cyclic, actinomorphic, and generally petamerous: calyx often gamosepalous: stamens usually definite: ovary unilocular, with basal placentæ.

Order 1. CARYOPHYLLACEÆ. Flowers generally petamerous, with calyx and corolla, though the latter is suppressed in some cases; sepals distinct or coherent: stamens in two whorls, of which the inner is often wanting; ovary 2, 3, or 5-merous, unilocular, or multilocular at the base, with a central placenta or with a single basal ovule: fruit usually a capsule: leaves opposite, decussate: stems usually tumid at the nodes.

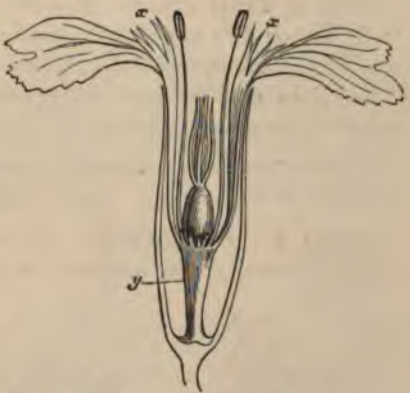


FIG. 265.—Longitudinal section of the flower of *Lychnis Flos Jovis*: *y* prolonged axis between the calyx and the corolla; *x* ligular appendages or corona. (After Sachs.)

Tribe 1. *Alsineæ.* The corolla and the inner whorl of stamens are usually present; the calyx is eleutherosepalous; fruit a capsule; usually no stipules.

Sagina, Arenaria, Alsine, Cerastium, Stellaria, Spergula, Holosteum, and others, are small herbaceous plants with white petals, occurring in meadows, on roadsides, etc.; they are distinguished from each other principally by the number of carpels present and by the mode of dehiscence of the fruit.

Tribe 2. *Sileneæ.* The corolla and the inner whorl of stamens are always present: the calyx is gamosepalous; stamens 10, filaments connate at base: the fruit is a capsule (in Cucubalus a berry): the leaves have no stipules; the floral axis is often elongated between the calyx and the corolla (Fig. 265 *y*): the petals (as in Lychnis and Saponaria) often have ligular appendages (Fig. 265 *x*).

The species of Dianthus, the Pink, which commonly occur wild are *D. deltoides* and *Armeria; D. Caryophyllus*, the Carnation, and *D. chinensis* are well-known garden flowers: there are two styles and the calyx is surrounded at its base by bracteoles. The genus Saponaria has two styles but no bracteoles; *S. officinalis*, the Soap-wort, occurs on the banks of rivers. The genus Silene (Catchfly) has three styles; *S. inflata*, *nutans*, and others, are common in meadows. The genus Lychnis (Campion) has five styles; the species *vespertina* and *diurna* are diœcious. *Agrostemma Githago*, the Corn-cockle, is common in fields.

Tribe 3. *Polycarpeæ*. Leaves with scarious stipules: calyx eleutherosepalous; the corolla is present, but the inner whorl of stamens is wanting: style 3-fid. This group includes the genus Polycarpon and others.

Tribe 4. *Paronychieæ*. Leaves with scarious stipules: sepals distinct or coherent: the corolla and the inner whorl of stamens are usually wanting: style usually bifid: ovary unilocular, with a single ovule.

Scleranthus annuus and *perennis* (Knawel), Herniaria, Corrigiola, and Illecebrum are small inconspicuous herbs.

Order 2. PORTULACACEÆ. Calyx usually of 2 sepals and corolla of 5 petals; stamens usually 5, epipetalous; ovary usually trimerous and unilocular; fruit a capsule. They are herbs with alternate or opposite leaves; the corolla is fugacious.

Portulaca oleracea, the Purslane, from Southern Europe, and other species are cultivated as vegetables and as ornamental plants. Montia (Blinks) has a gamopetalous corolla, slit up one side; it grows in ditches or in damp places.

Order 3. TAMARISCINEÆ. Flowers actinomorphic, 4- or 5-merous, with one or two whorls of stamens: calyx gamosepalous: ovary usually trimerous, unilocular, with basal or parietal ovules: capsule loculicidal: seed without endosperm, having a crown of hairs: flowers in racemes or spikes.

The genus Tamarix is indigenous in Southern Europe; *T. gallica* has become naturalized in England.

Cohort 4. **Polygalinæ.** Flowers actinomorphic or zygomorphic, usually pentamerous: sepals usually distinct: stamens definite: gynœcium usually of two carpels; ovary usually bilocular.

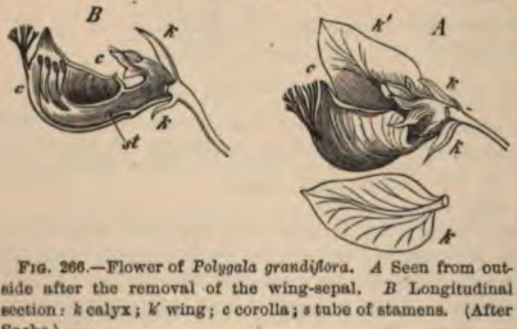


FIG. 266.—Flower of *Polygala grandiflora*. *A* Seen from outside after the removal of the wing-sepal. *B* Longitudinal section: *k* calyx; *k'* wing; *c* corolla; *s* tube of stamens. (After Sachs.)

Order 1. POLYGALACEÆ. Flowers zygomorphic; the two lateral sepals conspicuously large and known as "wings" (Fig. 266 *k'*); petals three, the two lateral being absent; the anterior petal is very large and carinate: stamens usually eight, forming a tube open posteriorly, to which the corolla, or at least the anterior petal, is adnate (Fig. 266): carpels two, median, forming a bilocular ovary, each loculus containing a single suspended ovule: fruit usually a capsule. The flower somewhat resembles that of the Papilionaceæ, but it must be borne in mind that here the two "alæ" or wings belong to the calyx.

Polygala vulgaris, *amara*, and others, are herbs, woody at the base, occurring in woods and meadows.

Order 2. PITTOSPOREÆ. Flowers actinomorphic: stamens five: ovules numerous, attached to the usually unconnected septa: leaves simple, exstipulate.

Pittosporum Tobira, *undulatum*, *crassifolium*, are ornamental plants from Australia.

Cohort 5. **Parietales.** Flowers cyclic, with calyx and corolla: sepals free: stamens definite or indefinite: gynœcium of two or more carpels; ovary unilocular or many-chambered: parietal placentation: seed with or without endosperm.

Order 1. PAPAVERACEÆ. Flowers actinomorphic, $K2$, $C2 + 2$, $A\infty\ G^{(2)}$ or (∞), or rarely with trimerous whorls: calyx sepaloid, corolla petaloid: the numerous whorls of stamens alternate: ovary of two lateral carpels (in Fig. 267 *A* they have been wrongly represented as being median) or of more (Fig. 267 *a*), two- or more-chambered: ovules numerous, attached to the slightly infolded edges of the carpels: endosperm abundant, embryo small. The sepals commonly fall off before the flower expands (Fig. 267*K*). Plants with abundant milky juice.

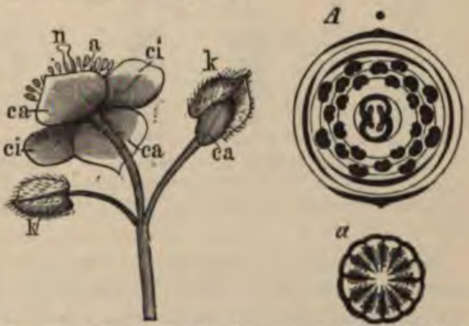


FIG. 267.—Flower of *Chelidonium majus* (nat. size): *k* calyx; *ca* outer; *ci* inner petals; *a* stamens; *n* stigma. *A* Diagram of the flower of *Chelidonium* (the carpels ought to be lateral): *a* Gynœcium of *Papaver*.

Papaver, the Poppy, has a many-chambered ovary; the fruit is a porous capsule (Fig. 160 *D*). *P. somniferum* is cultivated for the sake of the oil contained in the seeds, and as a medicinal plant: *P. Rhœas* is common in cornfields. *Chelidonium majus*, the Celandine, has two carpels, a siliquose fruit and orange-coloured milky juice. *Eschscholtzia californica* is a cultivated plant; it has a hollow receptacle, so that its flowers are almost perigynous.

Order 2. FUMARIACEÆ. Flowers usually zygomorphic with lateral symmetry: floral formula $\Rightarrow K2,\ C2+2,\ A2+2,\ G^{(\underline{2})}$. The three whorls of the perianth alternate; one of the outer petals (rarely both) is furnished with a spur: the two inner stamens are not in their normal position; each of them is divided and the two halves are displaced towards the outer stamens; hence there appear to be three stamens on each side, a central one, with a perfect anther (the stamen of the outer whorl, Fig. 268 *B a*), and two lateral stamens, each with only half an anther (the halves of the stamens of the inner whorl; Fig. 268 *B* $a_{,}\ a_{,}$). The fruit is siliquose and many-seeded, or one-seeded and indehiscent. Plants without milky juice. Seeds containing endosperm.

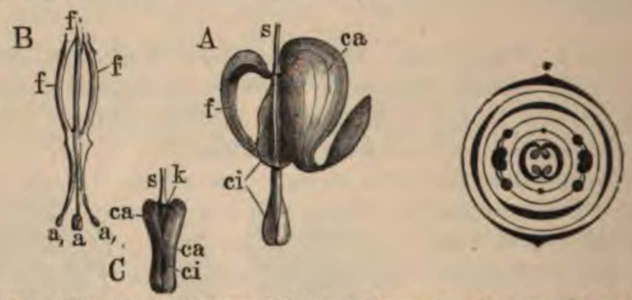


FIG. 268.—*A* Flower of *Dielytra spectabilis*; one of the outer petals is removed: *s* pedicel; *ca* the outer, *ci* the inner petals; *f* stamens. *B* The three stamens of one side, seen from within: *f* filaments; *a* the middle complete anther; *a, a,* the lateral half anthers. *C* Flower-bud, with the sepals, which soon fall off, still adhering (*k*) (nat. size). Diagram of Fumitory.

Dielytra (*Dicentra*) *spectabilis* is a favourite ornamental plant; both the outer petals are spurred, the two inner petals are hollowed at their apices, so that they completely close the anthers. In *Corydalis cava* and *solida* only one of the outer petals is spurred, the fruit is a two-valved capsule with numerous parietal seeds; these species have a tuberous rootstock; others, as *C. lutea* and *aurea*, have rhizomes. *Fumaria officinalis* and others (Fumitories) are common in fields; the ovaries contain but few ovules, and of these only one ripens to a seed; fruit globose, indehiscent.

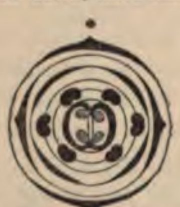


FIG. 269.—Diagram of the flower of Cruciferæ.

Order 3. CRUCIFERÆ. Flowers usually actinomorphic: floral formula $K2+2,\ C\times 4,\ A2+2^2,\ G^{(\underline{2})}$. The four petals form a whorl, alternating with the four sepals as if the latter formed one whorl; there are, however, three perianth-whorls, as in the two preceding families; but whereas in them only the outermost whorl is sepaloid, in this family the two outer whorls are sepaloid, and the innermost, which alone is petaloid, is a whorl consisting of four instead of two members. The two outer stamens are lateral, as in those families; the two inner ones, which in the Fumariaceæ are divided, are here duplicate, having longer filaments (Fig. 270 *B b b*) than the outer ones (*a*); hence the flower is *tetradynamous*. There are often minute glands at the base of the ovary (Fig. 270 *B d*). The ovary consists of two carpels with the ovules in two longitudinal rows on the adnate margins of the carpels; these two parietal placentæ are connected by a membranous growth which, as it is not formed of the margins of the carpels, must be regarded as a spurious dissepiment (Figs. 270 D^* E^*, 160 *C w*). When the fruit opens, the pericarp splits into two valves corresponding to the carpels, leaving the placentæ attached to the dissepiment forming the *replum;* the seeds remain attached to them for some time (Fig. 160 *C*).

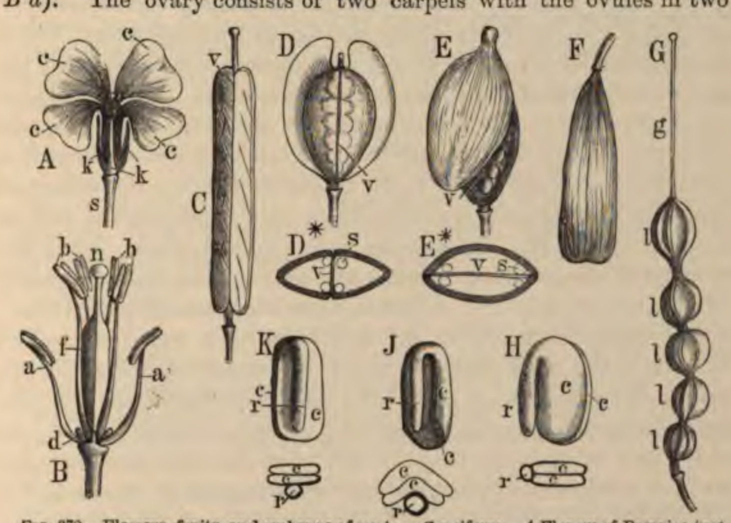


FIG. 270.—Flowers, fruits, and embryos of various Cruciferæ. *A* Flower of Brassica (nat. size): *s* pedicel; *k k* calyx; *c* corolla. *B* The same after removal of the perianth (much mag.): *a a* the two outer short stamens; *b* the four longer inner ones; *f* the ovary; *n* the stigma. *C* Siliqua of *Brassica : v* dissepiment. *D* Angustiseptal silicula of Thlaspi. *E* Latiseptal silicula of Draba. D^* and E^* Diagrammatic transverse section of the preceding: *v* dissepiment; *s* seed. *F* Indehiscent silicula of Isatis. *G* Jointed siliqua of *Raphanus Raphanistrum : g* style; *l l l* separate segments. *K–H* Diagrams of differently-folded embryos, with transverse sections: *r* radicles; *c c* cotyledons.

The flowers are in racemes in which the bracts are suppressed; when the lower pedicels are longer than the upper ones, the raceme becomes a corymb, and then the lower flowers are usually zygomorphic, the petals turned towards the periphery being larger than those directed towards the axis of the inflorescence, as in Iberis.

The form of the fruit is of importance in the sub-division of this order. In some genera it is much longer than it is broad, when it is termed a *siliqua* (Figs. 270 *C*, 160 *C*); in others, it is not much longer, or about as long as it is broad, when it is termed a *silicula* (Fig. 270 *D* and *E*). The latter is commonly somewhat compressed in one direction; either parallel to the dissepiment, that is to say laterally (Fig. 219 *E* and *E**), so that the dissepiment lies in the direction of the greatest diameter, when it is *latiseptal*, or perpendicularly to the dissepiment, that is in the median plane, so that the dissepiment lies in the narrowest diameter, when it is *angustiseptal* (*D* and *D*).* Fruits with only one or a few seeds, and which are indehiscent, are confined to only a few genera, such as Isatis (Fig. 270 *F*). So likewise is the jointed siliqua, which has transverse dissepiments between the seeds; when they are ripe it divides transversely into segments, as in Raphanus (Fig. 270 *G*).

The embryo is folded in the seed in various ways; the radicle may lie in the same plane as one of flat cotyledons (Fig. 270 *K*), when the cotyledons are said to be *incumbent*, *Notorhizeæ* (the diagram being ○ ‖); or the radicle may occupy the same position, the cotyledons being folded (Fig. 270 *J*), when the cotyledons are said to be *incumbent* and *folded*, *Orthoploceæ* (diagram of section ○ ≫); or, thirdly, the radicle may be lateral to the two cotyledons (Fig. 270 *H*), when the cotyledons are said to be *accumbent*, *Pleurorhizeæ* (diagram ○ =): more rarely the cotyledons are spirally rolled so that in a transverse section they are cut through twice, *Spirolobeæ* (diagram ○ ‖ ‖); or, finally, they may be doubly folded, and be seen four times in a section, *Diplocolobeæ* (diagram ○ ‖ ‖ ‖ ‖). The seeds contain much fatty oil.

Sub-order 1. SILIQUOSÆ. Fruit a siliqua, much longer than it is broad.

Tribe 1. *Arabideæ*. ○ =. *Cheiranthus Cheiri*, the Wall-flower; *Matthiola annua* and *incana*, the Stock, are cultivated as garden plants. *Nasturtium officinale* is the Water-cress. *Barbarea vulgaris* is the Yellow Rocket. Cardamine and Dentaria also belong to this tribe.

Tribe 2. *Sisymbrieæ*. ○ ‖. *Sisymbrium officinale*, the Hedge-Mustard, is common on rubbish heaps, and Erysimum on walls, etc. Hesperis is the Dame's Violet.

Tribe 3. *Brassiceæ*. ○ ≫. The species and varieties of Brassica are much cultivated. *Brassica oleracea* is the Cabbage, with the following varieties; *acephala*, Scotch kail, Cow-cabbage or Borecole; *bullata*, the Savoy cabbage:

capitata, the red and white Cabbage; *gongylodes* or *caulorapa*, with the stem swollen at the base, is the Kohl-rabi; *botrytis*, with connate fleshy peduncles and abortive flowers, is the Cauliflower; *gemmifera*, with numerous lateral leaf-buds, known as Brussels Sprouts. *Brassica rapa* is the Turnip, with bright green hispid leaves and flat corymbs of flowers; *Brassica Napus*, the Rape, has glabrous glaucous leaves and long racemes of flowers, and is cultivated for the sake of the oil contained in the seeds; both these species have fleshy underground stems. From *B. rapa* are derived the varieties *campestris*, the Summer-Turnip, and *oleifera*, the Winter-Turnip, as well as *rapifera*, with a fleshy root, the white Turnip. From *B. Napus* are derived the varieties *annua*, the Summer-Rape, and *hiemalis*, the Winter-Rape, which yield oil, and the variety *Napobrassica*, with an underground thickened stem, the Swedish Turnip. *Brassica nigra* and *Sinapis* (or *B.*) *alba* are the black and white Mustard. To this tribe belongs also the genus Diplotaxis.

Sub-order 2. SILICULOSÆ. Fruit a silicula.

A. *Latiseptæ.* The dissepiment is in the longest diameter of the silicula.

Tribe 4. *Alyssineæ.* ○ =. *Cochlearia officinalis* is the Scurvy-grass; *C. Armoracia*, the Horse-radish, has a thickened root. *Alyssum calycinum* and *Draba verna*, the Whitlow-grass (Fig. 270 *E*), are common weeds.

Tribe 5. *Camelineæ.* ○ ||. To this tribe belong Camelina (Gold-of-pleasure) and Subularia, the Awl-wort, an aquatic plant.

B. *Angustiseptæ.* The dissepiment is in the shortest diameter of the silicula.

Tribe 6. *Lepidineæ.* ○ ||. *Capsella Bursa Pastoris*, the Shepherd's Purse, is common, as also various species of Senebiera and Lepidium (Cresses).

Tribe 7. *Thlaspideæ.* ○ =. Various species of Thlaspi, the Penny Cress, are common. To this tribe belong also the British genera Iberis (Candy-tuft), Teesdalia, and Hutchinsia.

Sub-order 3. NUCUMENTACEÆ. Silicula indehiscent, few-seeded.

Tribe 8. *Isatideæ.* *Isatis tinctoria*, the Woad, has compressed pendulous fruits which are unilocular and one-seeded (Fig. 270 *F*): it is used as a blue dye.

Sub-order 4. LOMENTACEÆ. Fruit a siliqua or silicula, constricted into one-seeded segments (*lomentaceous*) (Fig. 270 *G*).

Tribe 9. *Cakilineæ.* Silicula two-jointed. This tribe contains the genera Cakile, the Sea-Rocket, and Crambe, the Sea-Kale.

Tribe 10. *Raphaneæ.* Silicula more or less moniliform. *Raphanus sativus* is the Radish; *R. Raphanistrum*, the Wild Radish or White Charlock, is a common weed.

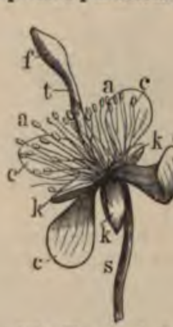


FIG. 271.—Flower of *Capparis spinosa* (nat. size): *s* pedicel; *k* calyx; *c* corolla; *a* stamens; *f* ovary on (*t*) gynophore.

Order 4. CAPPARIDEÆ. Flowers actinomorphic; formula $K2+2$, $C\times 4$, $A2+2^2$ or ∞, $G^{\underline{(2)}}$ or ∞: stamens only very rarely 6 and tetradynamous: ovary borne on a special prolongation of the axis (gynophore) (Fig. 271 *t*). Fruit a siliqua or a berry.

The flower buds of *Capparis spinosa* from the south of Europe are known as Capers.

Order 5. Resedaceæ. Flowers zygomorphic, sepals and petals 5–8, the latter laciniate: stamens numerous: carpels 2–6-connate, forming a unilocular ovary, open at the apex, with numerous ovules; seed without endosperm: inflorescence a raceme, without bracteoles.

Reseda luteola, the Dyer's weed, is useful as a yellow dye; *R. odorata* is Mignonette.

Order 6. Cistineæ. Flowers actinomorphic, usually pentamerous: the two external of the five sepals are generally smaller, and sometimes they are absent: stamens numerous, probably in consequence of branching; carpels 3 or 5, forming a uni- or multilocular ovary: ovules orthotropous: seed with endosperm. Trees or shrubs with generally opposite stipulate leaves.

Cistus ladaniferus, *creticus*, and other species, grow in the south of Europe; a balsam is derived from them. *Helianthemum vulgare*, the Rock Rose, is an under shrub which grows wild on dry soils.

Order 7. Bixaceæ. The seed of *Bixa orellana*, a native of America, yields an orange-coloured dye known in commerce as Annatto.

Order 8. Violarieæ. Floral formula $K5$, $C5$, $A5$, $G^{(2)}$: flowers always borne laterally: ovules anatropous: fruit a loculicidal capsule (Fig. 272 *C*): seed with endosperm. The indigenous species have zygomorphic flowers; the anterior inferior petal is prolonged into a hollow spur (Fig. 272 *A c s*) in which the nectar secreted by the spur-like appendages of the lower stamens collects (Fig. 272 *A f s*). The sepals are produced at the base (Fig. 272 *A ls*).

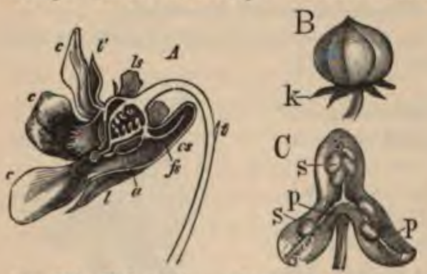


Fig. 272.—*Viola tricolor*. *A* Longitudinal section of flower: *v* bracteole of the peduncle; *l* sepals; *ls* appendage; *c* petals; *cs* spur of the lower petal; *fs* spur-shaped appendage of the lower stamens; *a* anthers. (After Sachs.) *B* Ripe fruit: *k* calyx. *C* After dehiscence: *p* placentæ; *s* seeds (mag.).

Viola is the Violet, Pansy, or Heart's-ease; many species, as *V. odorata*, the Sweet Violet, have only an underground stem which bears cataphyllary leaves, and which throws up petiolate foliage-leaves and bracteolate peduncles, each bearing a single flower: *V. odorata* has runners, but *hirta* and *collina* have none. In others, as *V. canina*, the Dog-violet, the main stem is above ground and bears the foliage-leaves. In *V. mirabilis* these two forms are so combined that in the spring flowers are developed from the rhizome which have large blue petals, but which are always sterile; it is not till later that inconspicuous (cleistogamous) flowers with minute petals appear on the leafy stem and these only are fertile. In *V. tricolor* and its allies, the stipules are leafy and pinnatifid.

Order 9. SARRACENIACEÆ. Flowers actinomorphic, hermaphrodite, with 15 or more stamens.

The leaves of Sarracenia and Darlingtonia are adapted, by the peculiar development of their laminæ, for the capture of insects.

Cohort 6. **Ranales.** Flowers generally acyclic or hemicyclic; perianth consisting of calyx only, or of calyx and corolla; stamens usually indefinite: gynœcium apocarpous, often reduced to a single monomerous ovary; very rarely polymerous and syncarpous. Seeds with or without endosperm.

Order 1. RANUNCULACEÆ. Perianth either consisting of a petaloid calyx, or of calyx and corolla, usually spiral: stamens numerous, occupying several turns of the spiral, or arranged in several alternating whorls, anthers bilocular, extrorse (introrse in Actæa and Pæonia); ovaries numerous, spirally arranged; rarely one only (Actæa). The ovules are disposed on the two margins of each carpel, that is, in two rows down the ventral suture; in several genera the number of the ovules in each carpel is reduced to one, which then originates from either the upper or the lower end of the cavity of the ovary. Seeds with endosperm. They are almost all herbaceous plants, and are either annuals or they have perennial rhizomes; they have no stipules, but they have amplexicaul leaves or petioles.

Tribe 1. *Clematideæ.* Petals transformed into stamens: sepals petaloid, with valvate æstivation: ovaries numerous, each containing a single suspended anatropous ovule. Climbing or creeping shrubs with opposite leaves. Fruit consists of a number of achenes.

Clematis Vitalba, the Old Man's Beard, is common in hedges; it has a greenish-white calyx, and fruits with long feathery styles: *C. Viticella, patens*, and others, are cultivated as decorative plants. *Atragene alpina*, occurring in the Alps and in Siberia, has its external stamens converted into petaloid staminodes.

Tribe 2. *Anemoneæ.* Petals transformed into stamens: sepals petaloid, with imbricate æstivation: ovaries usually numerous, each containing a single suspended ovule: fruit consists of a number of achenes.

Thalictrum; the species of this genus, as *T. minus, flavum*, and *aquilegifolium*, the Meadow-Rues, have stems well covered with leaves, and flowers with an inconspicuous, fugacious, 4–5-leaved calyx, and a flat receptacle. Anemone has an hemispherical receptacle (Fig. 273 *A t*), and a petaloid, usually 5–6-leaved calyx. In most of the species the underground rhizome elongates into an erect scape which bears a single whorl of three leaves forming an epicalyx beneath the terminal flower. In *A. nemorosa*, *ranunculoides*, and others, these leaves resemble the foliage-leaves and often bear flowers in their axils; but in *A. Pulsatilla*, and others, they differ from the foliage-leaves in that they are palmatifid (Fig. 273 *A h*); in *A. Hepatica*, in which the scapes spring from the axils of cataphyllary leaves, the three bracteoles are simple and lie so closely under the petaloid calyx that at first they appear to be the calyx of the flower.

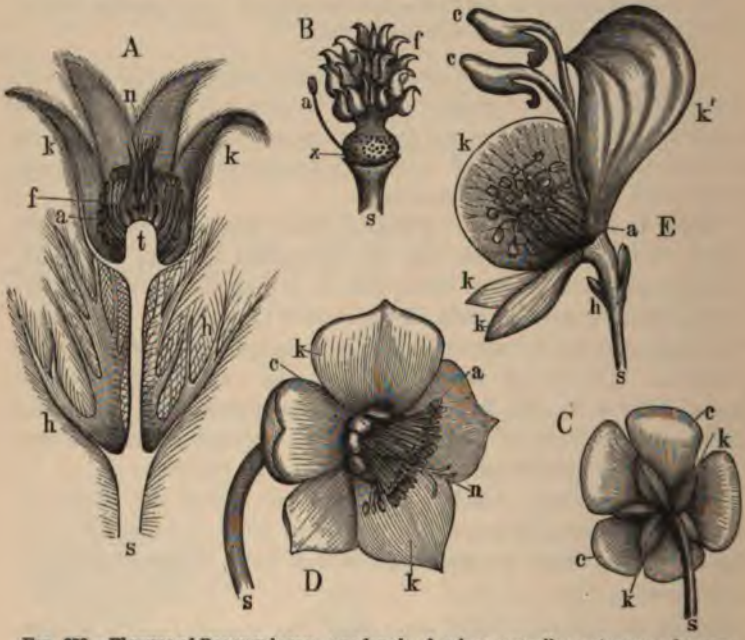


FIG. 273.—Flowers of Ranunculaceæ: *s* peduncle; *k* calyx; *c* corolla; *a* stamens; *f* ovary; *n* stigma (all of natural size or slightly magnified). *A* Of *Anemone Pulsatilla*, longitudinal section: *h* epicalyx; *t* receptacle. *B* Gynœcium of Ranunculus: *z* receptacle with the points of insertion of the stamens which have been removed. *C* Flower seen from below. *D* Flower of *Helleborus viridis*. *E* Of *Aconitum Napellus*: *h* bracteoles; *k'* hooded posterior sepal—the lateral sepal on this side is removed.

Tribe 3. *Ranunculeæ*. Perianth consisting of calyx and corolla: sepals imbricate: fruit an achene, with a usually ascending ovule (suspended in Adonis and Myosurus).

Ranunculus; the calyx consists of five sepals and the corolla of five petals which alternate with the sepals and have a nectary at their base; the stamens and carpels are arranged spirally.

The genus includes water-plants with finely-divided leaves and white flowers, as *R. aquatilis*, Water crowfoot, *fluitans*, etc.; and land or bog plants usually with a yellow corolla, as *R. acer*, the Buttercup, *repens*, *bulbosus*, and *sceleratus* (all known as Crowfoot), and *Flammula* (Lesser Spearwort); they are all more or less poisonous. *R. Ficaria* (the Lesser Celandine) has 3 sepals and usually 8 petals. *Myosurus minimus* (Mouse-tail) has a very long cylindrical receptacle; the sepals are spurred, and the petals gradually pass into the stamens. Adonis, the Pheasant's Eye, has completely acyclic flowers; sepals 5, petals 8 or more, not glandular at the base; stamens and carpels indefinite, arranged in $\frac{5}{13}$ order. *A. autumnalis* is the species which occurs in England.

Tribe 4. *Helleboreæ*. Perianth generally consisting of calyx and corolla, the latter being occasionally suppressed; the petals are glandular at the base; ovaries usually fewer in number than the leaves of the perianth; ovules numerous, borne on the ventral suture; fruit usually consists of several follicles.

(*a*) With actinomorphic flowers:

Helleborus, with acyclic flowers; sepals in $\frac{2}{5}$ arrangement; the petals, which are small and tubular, in $\frac{3}{8}$ or $\frac{5}{13}$; stamens in $\frac{8}{21}$ or $\frac{8}{21}$; ovaries usually 3–5 (Fig. 273 *D*). *H. niger* is the Christmas Rose; *H. viridis* and *foetidus* are not rare. Nigella has 5 petaloid sepals and usually 8 (superposed if 5) small glandular petals. Trollius, the Globe-flower, has 5–15 petaloid sepals, and a similar number of small petals which, like the stamens, are arranged spirally: *T. europæus* occurs in sub-alpine regions. Caltha, the Marsh-Marigold, has five yellow petaloid sepals but no corolla: *C. palustris* is common in damp places. Eranthis, the Winter Aconite, has small petals with long claws. Actæa has a petaloid calyx and an alternating (sometimes suppressed) corolla; it has a single carpel which becomes a baccate fruit: *A. spicata*, the Baneberry or Herb Christopher, occurs in woods. Aquilegia, the Columbine, has a cyclic flower (Fig. 274): it has five petaloid sepals, and petals with long spurs: *A. vulgaris*, *atrata*, *Aklei*, and others occur wild or are cultivated as decorative plants.

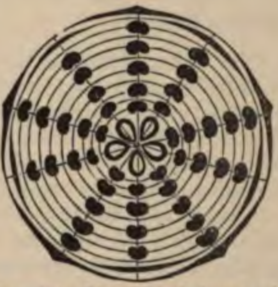


FIG. 274.—Diagram of flower of Aquilegia.

(*b*) With zygomorphic flowers:

Delphinium, the Larkspur, has the posterior of the five petaloid sepals prolonged into a spur: there are typically 5–8 petals, of which only the two (or four) posterior are developed, their spurs projecting into that of the posterior sepal. *D. Staphisagria* is poisonous; *D. consolida* has but one carpel; *D. Ajacis* is a common garden plant, with 1–5 carpels. In Aconitum, the Wolf's-bane or Monk's-hood, the posterior of the 5 petaloid sepals is large and hooded; the two posterior of the 8 petals have long claws and are covered by the posterior sepal, the others being inconspicuous (Fig. 273 *E c*).

Sub-order 4. *Pæonieæ*. The perianth consists of calyx and corolla, and the petals are not glandular: ovaries with numerous ovules, surrounded by a disc.

In Pæonia, the Pæony, the calyx consists of 5 sepals which gradually pass into the foliage-leaves; the 5 or more petals are larger: the stamens are spirally arranged. *P. officinalis*, *corallina*, and others are cultivated as decorative plants; *P. Moutan* has a woody stem and a tubular disc. Fruit consists of several follicles.

Order 2. MAGNOLIACEÆ. Perianth cyclic, consisting usually of three alternating trimerous whorls, one of sepals and two of petals: stamens and carpels numerous, arranged spirally: seed containing endosperm. Woody trees or shrubs.

Tribe 1. *Magnolieæ.* Carpels very numerous on an elongated cylindrical receptacle: flowers invested by a spathoid bract; stipules connate. *Magnolia grandiflora* and other species, and *Liriodendron tulipifera* (the Tulip-tree) from North America, are ornamental trees.

Tribe 2. *Illicieæ.* Carpels in a simple whorl on a flat receptacle (Fig. 158). *Illicium anisatum*, the Star Anise, is a native of China.

Order 3. CALYCANTHACEÆ. Flowers acyclic, perigynous.

Calycanthus floridus is an ornamental shrub with brown aromatic leaves.

Order 4. NYMPHÆACEÆ. Flowers usually acyclic without any sharp demarcation between the petals and the stamens; pistil either apo- or syncarpous. Water-plants, generally with broad floating leaves.

Tribe 1. *Nymphæinæ.* Carpels connate, forming a polymerous multilocular ovary which may be either superior or inferior. Ovules numerous, placentation superficial: seeds numerous, containing both endosperm and perisperm. The rhizome grows at the bottom of the water and throws up broad flat cordate leaves with long petioles which float on the surface. The flower also reaches the surface, borne on a long peduncle.

Nymphæa alba, the white Water-Lily, has four green sepals, a great number of white petals which, together with the very numerous stamens, are arranged spirally, and a semi-inferior ovary. *Nuphar luteum*, the yellow Water-Lily, has a calyx consisting of five greenish-yellow sepals; the petals, which are smaller and yellow, are usually 13 in number, and form a continuous spiral with the indefinite stamens; the ovary is superior. *Victoria regia*, a Brazilian species, has peltate leaves of more than a yard in diameter.

Tribe 2. *Nelumbieæ.* Ovaries numerous, distinct, imbedded in the fleshy receptacle: seeds solitary, without endosperm.

Nelumbium speciosum is the Lotus of Egypt and Asia.

Tribe 3. *Cabombeæ.* Flowers cyclic. Ovaries numerous, monomerous, each with from 2 to 3 ovules attached to the dorsal suture of the carpel. Seeds containing endosperm and perisperm. The submerged leaves are much divided, the floating leaves peltate. America and the East Indies.

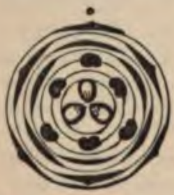


FIG. 275.—Diagram of flower of many of the Menispermaceæ.

Order 5. MENISPERMACEÆ. Flowers diœcious, cyclic; the whorls are usually trimerous, and the calyx, corolla, and andrœcium have at least two whorls each. Carpels usually 3–6, distinct, one-seeded, but many-seeded in the sub-family Lardizalbeæ. They are tropical climbing plants with herbaceous stems and palmate leaves.

Order 6. BERBERIDEÆ. Flowers hermaphrodite, cyclic, the calyx, corolla, and andrœcium, each consisting of two di- or trimerous whorls. Ovary monomerous, with numerous marginal ovules. Fruit capsular or baccate. Seed with endosperm.

Berberis vulgaris is the Barberry ; its floral formula is $K3+3$, $C3+3$, $A3+3$ $G^{\underline{1}}$; the flowers are in pendent racemes, usually without terminal flowers ; when a terminal flower is present its formula is $K5 \mid C5 \mid A5$. Fruit an oval berry. The leaves of the ordinary shoots are transformed into spines (Fig. 12), in the axils of which are dwarf-shoots bearing the foliage-leaves and the inflorescences. Epimedium has a dimerous flower ; calyx of 1–5 whorls ; petals spurred.

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Butler & Tanner, The Selwood Printing Works, Frome, and London.

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